U.S. Department
of Transportation

Federal Aviation Administration

800 Independence Ave., S.W.
Washington, D.C. 20591

JAN 15 1992

Dear Colleague:

Enclosed is a copy of FAA report **FAA/DS-89/10 entitled "Rotorcraft Low Altitude IFR Benefit/Cost Analysis: Operations Analysis."** This is the second in a set of three reports on this topic. The objective of this study is to determine if there is an economic basis for improving low altitude instrument flight rules (IFR) services within the National Airspace System. This second report documents the following:

1. Definition of the IFR operational requirements of the missions selected as most likely to benefit from additional low altitude IFR services.

2. Selection of 50 sites around the country where the nation would be most likely to derive additional benefits from increased low altitude IFR services.

3. Identification of low altitude radar and communications coverage and areas where improved coverage is needed.

4. Identification of changes to FAA policies/air traffic control procedures that would increase the safety and efficiency of vertical flight aircraft operations.

5. Development of a benefit/cost methodology to be used in later analysis to identify locations where benefits would accrue from improvements in low altitude IFR services or changes in air traffic control procedures.

When this effort was started, the FAA considered the lack of low altitude communications, surveillance, and navigation coverage to be the principal obstacle to expanded IFR flight by vertical flight aircraft. Analysis has shown, however, that there are other considerations of greater issue.

When the third document is published and this study is completed, we expect that it will make a significant contribution in the FAA's efforts to better integrate vertical flight aircraft into the National Airspace System.

James I. McDaniel
Manager, Vertical Flight Program Office

Enclosure: FAA/DS-89/10

DOT/FAA/DS-89/10

Research and Development Service
Washington, D.C. 20591

Rotorcraft Low Altitude IFR Benefit/Cost Analysis:

Operations Analysis

Robert K. Anoll
Len D. Dzamba
Linda J. LaBelle
Randahl N. Lindgren
Robert B. Newman
Deborah J. Peisen

Systems Control Technology, Inc.
1611 N. Kent Street, Suite 910
Arlington, VA 22209

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Interim Report

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16. Abstract

The Rotorcraft Master Plan advocates the establishment of additional communications, navigation, and surveillance (CNS) facilities, as well as the analysis and development of systems to satisfy the increasing demand for widespread IFR rotorcraft operations within the NAS. The objective of this study is to determine if there is an economic basis for improvement of these low altitude instrument flight rules (IFR) services within the National Airspace System (NAS) in order to better support rotorcraft IFR operations. The findings of this study will aid FAA decisionmaking in that regard. In view of prior implementation decisions on Loran-C, the emphasis in this effort is on communications, surveillance, procedural changes, and avionics.

This report is one of a series of three reports that address rotorcraft low altitude IFR benefit/cost analysis. The other two are:

1) Rotorcraft Low Altitude CNS Benefit/Cost Analysis: Operations Data, DOT/FAA/DS-89/9,
2) Rotorcraft Low Altitude IFR Benefit/Cost Analysis: Methodology and Applications DOT/FAA/RD-89/11.

This second interim report defines operational requirements and constraints for selected rotorcraft missions. A candidate list of 50 sites around the country, selected for their potential to benefit from increased low altitude IFR services, is presented. Radar and communications coverages in those areas are then identifed. CNS improvements to be provided by implementation of the NAS plan, relevant FAA policies, ATC procedures, and avionics improvements are analyzed for their potential to benefit low altitude rotorcraft IFR operations. Last, a benefit/cost methodology to determine where the most benefits would accrue from improvements in rotorcraft low altitude IFR services or changes in ATC procedures is presented.

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1.0 INTRODUCTION

The purpose of this benefit/cost study is to provide analytical material for decisionmaking in implementing new services, procedures, and equipment for improved rotorcraft operations by area. The Rotorcraft Master Plan (RMP) advocates establishment of additional communications, navigation, and surveillance (CNS) facilities or the development of alternative systems to satisfy the increased demand for rotorcraft instrument flight rules (IFR) operations. The findings of this study will aid FAA decisionmaking concerning this activity. In view of prior implementation decisions on long range navigation (LORAN-C) and the global positioning system (GPS) and an apparent resolution of the navigation issue, the emphasis in this effort will be on communications, surveillance, procedural changes, and avionics.

Current air traffic control (ATC) services and procedures have been designed around fixed-wing IFR operations on designated airways to and from airports. While rotorcraft frequently operate in the established ATC structure, by doing so they are limited in taking full advantage of their unique operating characteristics. Point-to-point area navigation capability and the ability to operate to and from any location cannot be fully used at this time, because at many locations and altitudes used by rotorcraft, ATC services and/or adequate CNS are not available. The data and analyses resulting from this study will be used to determine what additional services, procedures, and equipment are needed to meet rotorcraft operational requirements and the most cost-effective means for doing so.

This report is the second in the series of three reports. The first report, "Rotorcraft Low Altitude CNS Benefit Cost Analysis: Rotorcraft Operations Data," DOT/FAA/DS-89/9 published in September 1989, established and consolidated the most current operations data needed to complete the analyses in subsequent tasks. Specifically, the types of missions typically performed by rotorcraft were identified, as well as a profile of flight characteristics for each mission. This was done so that each mission could be evaluated in terms of potential benefits resulting from increased IFR operations. Next, only those missions thought most likely to derive significant benefits were selected for further detailed analysis. Another section of the first report addressed geographic and weather factors that affected the density and frequency of rotorcraft operations in those areas where the missions of interest occurred. Last, previously published forecasts and sources of rotorcraft data were reviewed and an alternative forecast model was developed to estimate the number of current active rotorcraft and flight hours, expected future growth rates, and rotorcraft fleet characteristics by specific mission.

This second report builds and expands on the operational data collected and analyzed in the first report. While the first report considered the entire conterminous United States (CONUS) in its analyses of rotorcraft data, this report focuses on 50 specific sites around the country selected for their potential to benefit from increased low altitude IFR services.

The last report, "Rotorcraft Low Altitude IFR Benefit Cost Analysis," Final Report, DOT/FAA/DS-89/11, describes the requirements for CNS functions in rotorcraft operations and provides site qualification criteria based on the number and characteristics of rotorcraft operations. The report also develops a generic benefit/cost methodology for computation of improved low-altitude

IFR services and applies the methodology to assess the need for increased services at 50 sites.

When this effort was started, FAA thinking was that the key problem was the lack of coverage. This perspective is reflected in the title of the first interim report: "Rotorcraft Low Altitude **CNS** Benefit/Cost Analysis." Analysis has shown that there are other considerations as well. This broader perspective is reflected in the titles of the second and third reports: "Rotorcraft Low Altitude **IFR** Benefit/Cost Analysis."

2.0 OBJECTIVES

The objectives of the analyses included in this report are as follows:

1. To further define operational requirements for the rotorcraft IFR missions selected for study in the first report. This examination includes the mission purpose, capabilities, time constraints, value or worth of the mission, and operational constraints.

2. To select a candidate list of 50 sites around the country, based on specific criteria, that would be likely to derive potential benefits from increased low altitude IFR services.

3. To identify existing radar and communications coverages in the present National Airspace System (NAS) and planned coverages as projected in the seventh annual update of the NAS Plan. To then examine coverage shortfalls and determine locations where improved CNS coverages are needed by the rotorcraft community.

4. To identify changes to FAA policies/air traffic control procedures and improvements to rotorcraft avionics which will benefit helicopter safety and efficiency in the future.

5. To develop a benefit/cost methodology that will be used in later tasks to identify locations where benefits would accrue from improvements in rotorcraft low altitude IFR services or changes in ATC procedures.

3.0 OPERATIONAL REQUIREMENTS

3.1 INTRODUCTION

Although rotorcraft can operate in the same manner and environment as fixed-wing aircraft, their vertical takeoff and landing and slow speed capabilities allow them to operate freely almost anywhere, from rugged, mountainous terrain to rooftops. This capability provides a great deal of flexibility in the missions they perform. For this study, only those missions thought most likely to derive significant benefits from improved low altitude IFR service were selected for detailed analysis. As described in the first report for this project, this selection was accomplished by developing criteria that determined possible benefits of low altitude IFR service for different helicopter missions. These criteria included an increased number of operations, increased safety, increased efficiency, time criticality, and value of the trip. The missions were then evaluated and ranked with regard to their potential to accrue benefits from increased IFR service. Those selected for further study were:

- Emergency Medical Service (EMS),
- Offshore,
- Air Taxi/Commercial,
- Search and Rescue (SAR),
- Business,
- Corporate/Executive, and
- Scheduled Commuter.

Their relative importance to society are shown in figure 1, Priority Ranking by Mission. Each of these missions has associated operational requirements that must be met in order to complete operations in both an efficient and cost-effective manner. Evaluating potential improvements in meeting these requirements determines to what extent each mission may benefit from improved low altitude IFR service. Identifying existing operational needs were founded upon interviews with operational personnel at the locations of interest

3.2 EMERGENCY MEDICAL SERVICE (EMS)

3.2.1 Mission Purpose

EMS operations fall into two categories: 1) accident scene pickup of victims; and 2) inter-hospital transfer of medically stable patients who require medical attention not available from the referring hospital. Accident scene pickups are currently done exclusively in visual flight rules (VFR) conditions, since landing at an accident scene requires the pilot to have good visual reference with the ground. Also, there is no protected airspace or approach guidance associated with an accident scene. While it is possible that future improvements to obstacle avoidance systems might some day allow IFR scene pickups, scene pickups will remain VFR for the foreseeable future and will not be considered further in this report.

MISSION	JUSTIFICATION
EMS, SAR	LIFE-SAVING BENEFITS
OFFSHORE	OFFSHORE OIL INDUSTRY LARGELY DEPENDENT ON THE HELICOPTER FOR TIMELY TRANSPORTATION
SCHEDULED COMMUTER, CORPORATE/EXECUTIVE	TIMESAVINGS, RELIABILITY CRUCIAL FOR SUCCESS
BUSINESS, AIR TAXI	ALTERNATE SLOWER MODES OF TRANSPORTATION COULD BE USED IF NECESSARY

HIGH

LOW

FIGURE 1 PRIORITY RANKING BY MISSION

Inter-hospital transfers include: 1) the transfer of various emergencies, such as burn and trauma patients, for which the referring physician feels additional specialized care and/or equipment is required; and 2) the transport of medical personnel and supplies, especially perishables such as blood products, transplant organs, and uncommon medicines. In recent years, in the United States, approximately 80 percent of EMS helicopter missions have involved inter-hospital transfers. Only about 20 percent of their missions involve accident scene pickups.

3.2.2 Capability

Most EMS operations are conducted in accordance with the FAA's recommended operating minimums set forth in EMS Advisory Circular (AC) No. 135-14A. These recommended visual flight rules (VFR) minimums are presented in table 1.

TABLE 1
RECOMMENDED EMS VFR MINIMUMS

	Uncontrolled Airspace	
	Ceiling	Visibility (Statute)
Day Local	500 ft	1 mile
Day Cross Country	1000 ft	1 miles
Night Local	800 ft	2 miles
Night Cross Country	1000 ft	3 miles

EMS helicopters are especially equipped and staffed to provide advanced life support during the transport period. This advanced life support is thought to be the primary reason for the higher survival rate among EMS transported patients over ground ambulance transported patients. For inter-hospital transfers, an EMS helicopter may reduce transport time by 30 to 80 percent compared to ground transported patients (reference 50).

Generally, EMS operations are based at a large hospital that is responsible for one or more types of specialty care for the entire regional area. On a typical mission, the helicopter flies directly to the referring hospital, picks up the patient, and then flies directly back to the base hospital. Under certain circumstances, such as instrument meteorological conditions (IMC) and/or lack of a suitable landing site at the referring hospital, the helicopter may pick up a patient at an airport or other designated landing site. However, when operations directly from hospital to hospital are not possible, much of the time advantage over other forms of transfer are lost. However, the patient still receives the benefit of advanced life support equipment and staff during the helicopter portion of the trip.

Most EMS operators do not operate in IMC and only 10 to 15 percent of EMS operators have IFR programs. Based on discussions with EMS operators (section

5.2), approximately 75 percent of the operators have partially IFR-equipped helicopters and IFR-rated pilots. These aircraft and pilot capabilities are primarily to increase the safety margin in the event of encountering deteriorating weather conditions. However, the percentage of EMS operators flying in IMC has been increasing and continued growth is expected. This mission operates under 14 CFR 135.

3.2.3 Time Constraints

Time criticality of EMS operations is of primary importance, since time saved in transporting a patient or victim may mean the difference between life and death, or may determine the ultimate severity of an injury. EMS operators strive for, and usually achieve, a quick response time.

3.2.4 Mission Value

The main value of the EMS mission is found both in the reduced mortality and the reduced severity and long term effects of injuries (morbidity) among patients transported. Society realizes additional benefits, since expensive specialty treatment centers, such as trauma centers, burn centers, neonatal centers, heart centers, etc., are tremendously expensive to maintain. The helicopter increases the areas such specialty centers can effectively serve, thus avoiding duplication of these expensive facilities.

3.2.5 Operating Constraints

A primary constraint for this mission is the fact that many operators do not believe IFR flights are appropriate for their mission. One reason for this belief is the lack of instrument approaches to most of the hospitals, heliports and/or local community airports served by EMS operators.

Weather may also be a significant factor affecting EMS operations, particularly if the aircraft is not IFR-certificated and/or the pilot is not IFR-rated. If the flight does proceed IFR, delays may be experienced in congested areas due to ATC system constraints. However, EMS operators may request priority handling from ATC when the life of a patient is in jeopardy by using the "Lifeguard" call sign authorized by FAA Order 7110.65F, paragraphs 2-4. Inadequate weather reporting, especially at night, is another problem. Lack of a weather observer in the area of the mission's destination often results in the operator refusing a mission rather than taking a risk in marginal weather.

3.3 OFFSHORE

3.3.1 Mission Purpose

Helicopter services are provided for the offshore petroleum and gas exploration and production industry in two major areas: the Gulf of Mexico, and the Arctic Ocean off the northern coast of Alaska. These two areas contain the bulk of offshore helicopter operations.

Helicopters are used in the offshore mission to transport workers and equipment between onshore staging areas and offshore drilling and production rigs. They are also used to provide service between rigs. In addition, helicopters are the prime means of providing emergency medical service to the rigs when personal injury or acute illness require medical evacuation.

3.3.2 Capability

Although VFR operations predominate in the offshore mission, there is a requirement for operation in all weather conditions. In Alaska there is a significant amount of IFR offshore helicopter activity from the North Slope. Exploration and drilling are restricted to winter months of near constant darkness because of ecological restrictions in spring and summer. Operations are largely conducted in uncontrolled airspace and at altitudes that vary according to the particular type of offshore mission.

In the Gulf of Mexico, helicopters routinely fly to rigs located from 100 to 160 miles from shore. Oil companies have announced that rigs will be sited more than 200 miles offshore by the end of the century. Already off the Alaskan west coast, Boeing BV234ERs have flown 400 miles offshore to exploratory oil rigs in the Navarin Basin located off Alaska's west coast. No drilling is now being performed in this area, however.

There are about 4,000 standing rigs in the Gulf of Mexico, most of which can accommodate some type of helicopter. Two types of helicopter operators serve the offshore mission: oil companies that operate their own helicopter fleets under 14 CFR Part 91 and companies who rent or lease their helicopter services to the oil companies under 14 CFR Part 135.

Operators of offshore helicopters utilize two unique capabilities to assist in mission accomplishment: LORAN-C flight tracking and offshore standard approach procedures (OSAP). Because surveillance radar service at low altitudes is only available relatively close to the radar antenna, positive flight following of offshore helicopter traffic in the Gulf is accomplished in-house by each company. This usually takes the form of individual companies running tracking systems for their own aircraft. These tracking systems display aircraft position data transmitted from the aircraft's LORAN-C receiver. Aircraft position and progress are displayed on a video screen. Operators at the home base can identify the locations of the company's own aircraft, but they cannot detect the aircraft of other tracking systems, a deficiency that could be overcome by a solid regional radar surveillance system or by a single LORAN-C tracking system such as the FAA's experimental LORAN-C offshore flight following (LOFF) program.

OSAPs were created to give helicopter offshore pilots the ability to make safe approaches to offshore rigs in IFR conditions. The instrument approaches use LORAN-C for course guidance and airborne weather/mapping radar for detecting and avoiding obstructions. Based on ceiling and visibility criteria as low as 200 feet and 3/4 mile, the procedure normally places the helicopter on a course offset to the rig of intended landing. If the landing area is spotted before minimums are reached, the pilot then takes over visually. Otherwise he/she executes a missed approach and climbs back to cruise

altitude. To fly the approach, a number of requirements must be met. Part 91 operators must have a letter of authorization and Part 135 operators must be approved for OSAP in the operator's specifications. Pilots must be IFR current and OSAP trained. Their helicopter must be IFR certificated plus have LORAN, a radar altimeter, and weather radar approved for OSAPs. An approved weather reporting station must also be located within 10 nautical miles of the approach target.

3.3.3 Time Constraints

Time is an important factor for the offshore mission but not in the same sense as for a scheduled carrier, where timeliness reflects the "on schedule" reputation of the operator. For the offshore operator, timeliness is more a function of fuel efficiency and operational efficiency. Delays in equipment delivery and/or crew changes can create additional costs for offshore operators in terms of paid overtime for personnel and interruptions in operations.

3.3.4 Mission Value

The value of the offshore mission should be classified as essential since it supports the vast majority of society through production of oil and gas. The offshore mission provides for the transport of crews, executive management and high priority equipment. In addition, the offshore mission supports hurricane evacuations and medical evacuations from offshore platforms in the event of emergencies. The helicopter is now accepted as an essential tool in the exploration, production, and management of the nation's resources.

3.3.5 Operating Constraints

Helicopters performing offshore missions generally fly using VFR. This is true both in the Gulf of Mexico and in Alaska. For geographic and meteorological reasons the Alaskan offshore mission demands a higher percentage of IFR flying. The added cost and payload penalty means the customer is ultimately the one who must decide if the added expense is warranted in fulfilling the mission's requirements. Communications and especially radar coverages are inadequate and, as a result, large IFR separation standards cause delays. Also the limited number of IFR offshore routes reduce the number of direct routes. The resulting inconvenience, delay, and higher costs tend to steer operations away from IFR flight unless absolutely required by the customer.

3.4 AIR TAXI/COMMERCIAL

3.4.1 Mission Purpose

Air taxi/commercial operations occur under 14 CFR Part 135. The missions that these commercial operators perform include photography, construction, powerline and pipeline patrol, survey, executive transport, small package pickup and delivery, sightseeing, and traffic reporting. As defined for this study, the air taxi/commercial mission encompasses all Part 135 operators except for those conducting offshore, scheduled commuter, or EMS operations.

3.4.2 Capability

Air taxi/commercial missions are flown in both urban and rural areas using helicopters ranging from single-engine piston operating VFR to twin-engine turbine aircraft operating IFR. These operators are found in all areas of the United States. However, there are differences in the air taxi/commercial missions depending on the part of the country in which the operator is located. For instance, in the Northeast executive transport may comprise a larger percentage of a commercial operator's operations than it would in Utah, where there would be a greater need to support geologic or seismic surveys. Throughout the country, most air taxi/commercial operations are based at airports in order to have access to fuel and maintenance facilities.

3.4.3 Time Constraints

Although air taxi/commercial missions are on-demand and not scheduled, time criticality is essential to business success. This is true both in the general sense, as customer satisfaction is important to any business, and for specific time critical missions, such as providing service for a busy executive who wishes to catch a commercial flight at the airport.

3.4.4 Mission Value

People use helicopters for three general purposes: to provide a faster mode of transportation, to access places no other vehicle can reach, or to perform tasks that cannot be performed in any other way. The air taxi/commercial use of helicopters embodies missions that satisfy all three purposes. However, those air taxi/commercial missions that satisfy the last two purposes, remote access and unique applications, are often not time dependent. The one purpose that is time dependent, the transport of passengers or property, can usually be done with alternate, albeit slower, modes of transportation if necessary. Consequently, the value of this mission is classified as average in terms of the overall range of helicopter operations.

3.4.5 Operating Constraints

Weather is a significant factor affecting air taxi/commercial operations if the aircraft is not IFR-certificated or the pilot is not IFR-rated, and VFR flight is not possible. If the flight is IFR and the weather is IMC, delays are often experienced in congested areas due to ATC system constraints.

3.5 SEARCH AND RESCUE (SAR)

3.5.1 Mission Purpose

SAR operations are performed throughout the United States. Often the missions involve the cooperative efforts of local law enforcement, military, civil air patrol, and other government personnel. Typical rescue missions include evacuating victims of floods, fires, volcano eruptions, avalanches, and earthquakes; and searching for lost, injured or ill persons and removing

them from remote areas such as those encountered while hiking, boating, and mountaineering.

The majority of the SAR flights are performed by government agencies and are therefore exempt from 14 CFR 91 or 135 requirements. However, many of these agencies use 14CFR91 as a part of their standard operating procedures.

3.5.2 Capability

This mission is performed mostly in rural, remote, and over water locations, at low altitudes, and under visual or marginal weather conditions in uncontrolled airspace. Night operations are commonplace when involved in time critical evacuation missions.

No established routes exist for search and rescue operations, as the routes flown vary widely with individual missions, local conditions, and terrain. If an operator repeatedly flies search and rescue missions to a particular area, such as a national park, special routes or procedures may be developed into the search area to provide expedient service.

3.5.3 Time Constraints

Time is critical to the success of this mission, as the chance for location and survival of a victim decreases with an increase in response time.

3.5.4 Mission Value

The value of this mission is of great magnitude because of the benefits associated with saving lives and reducing morbidity.

3.5.5 Operating Constraints

The main constraints affecting this mission are the difficult conditions in which these operations must take place, e.g., poor weather conditions, and remote surroundings such as wilderness areas and mountainous terrain. Finding suitable places to land may be difficult in very remote locations.

If conditions are IMC, the mission can not be flown until the weather improves, since being able to locate a victim visually is the primary function of the mission. This mission will therefore be excluded from the benefit/cost analysis.

3.6 BUSINESS

3.6.1 Mission Purpose

Business missions are primarily flown in support of small businesses by the proprietor of the business, who flies the helicopter himself/herself as an alternative to ground transportation. Helicopters are used in business for many reasons. These include the timesaving or productivity increasing aspects of the helicopter; aerial inspection of property, buildings, job sites, or operations; providing transportation for clients; providing transportation

from business offices to airports; and providing a higher degree of security for personnel and information than public transportation or surface transportation can offer.

3.6.2 Capability

Business flights are usually short range, carrying two to four passengers. The helicopters used are mostly single-engine piston or turbine aircraft flown during normal business hours in day VMC. Flight characteristics depend on the geographic location and airspace requirements. Most business flights operate under 14 CFR Part 91.

Business operations are variable and flexible. If repetitive flights between certain destinations are made, individual business operators may fly on specific routes established by letters of agreement with local ATC facilities. Other businesses may use charted VFR routes, such as those in the Washington, D.C., New York, Los Angeles, and Chicago areas.

3.6.3 Time Constraints

Time is important to this mission in terms of meeting schedules critical to the business's success.

3.6.4 Mission Value

The use of the helicopter for this mission increases efficiency and lowers the costs of the business it supports. The value of this mission, however, can be classified as average, since the transport of personnel or property can usually be done with alternate, slower modes of transportation if necessary.

3.6.5 Operating Constraints

One constraint for this mission is the fact that operations usually need to be conducted during business hours because of the nature of the mission. If weather conditions are IFR and the pilot is not IFR-rated or the aircraft is not IFR-certificated, a business deal may not be completed on time or a schedule may not be met because a flight could not operate. Another constraint is the lack of heliports in downtown business areas. Private heliports, parking lots, or suitable portions of company property are used at business offices and outlying facilities. Some business operators find basing at airports advantageous to allow quick transfer between airplane and helicopter for flights to the business office. However, many business operators would take advantage of public heliports, especially in city centers, if they were available.

3.7 CORPORATE/EXECUTIVE

3.7.1 Mission Purpose

Corporate/executive missions carry executives and other employees for company or individual business. Trips may be for the purpose of allowing management to visit locations and supervise operations which are not

conveniently accessible by other means of transportation. In addition, this mission may be used to move critical parts and personnel to remote sites in a timely manner to ensure minimal disruption of operations when problems occur. Typically, corporate/executive operators own their own helicopters but employ a professional flight crew to fly for them or the company. This mission primarily operates under 14 CFR Part 91.

3.7.2 Capability

Corporate/executive helicopter operators perform both scheduled and non-scheduled flights. The altitudes flown and whether the operation will be VFR or IFR depends on the location of the corporate operator in the United States, what industry the helicopter is supporting, and its local origin and destination. The heaviest concentration of this mission is located in the northeastern United States. The types of helicopters used range from the single-engine turbine to medium-sized, twin-turbine aircraft like the Sikorsky S-76.

Corporate/executive operations are primarily flown VFR. The only area where there is considerable use of IFR for helicopter operations is in the Northeast Corridor, especially in the Boston and New York City regions. This is due primarily to the extensive area covered by controlled airspace, the concentration of the larger, more fully equipped helicopters, and to the relative high probability of IMC in this part of the country.

The level of activity of the corporate/executive mission depends on the economic well-being of those businesses that use helicopters. Obviously, the more often the helicopter can fly in all weather conditions, the more economically attractive is its use. Helicopters used for this purpose are an alternative not only to ground transportation, but to short-haul, fixed-wing flights and sometimes to commercial fixed-wing transportation. Therefore, corporate/executive missions try to fly the most direct route possible under prevailing conditions.

Although some corporate users may have heliports at their headquarters, branch offices, or both, most of these heliports do not have fuel and maintenance facilities. The helicopters are often based at a nearby airport, with company heliports used only to pick up and drop off passengers and cargo.

3.7.3 Time Constraints

Timeliness is important to this mission since flights must meet an individual's or company's schedule. In essence, in the world of business, time wasted means money wasted or business opportunities lost. One of the major advantages of using rotorcraft to accomplish the corporate/executive mission is to bring widely dispersed operations within the management span of control, thus enhancing the use of valuable and scarce executive time. Time saved is especially significant in congested areas, where trips using ground transportation would take much longer.

When high-level executives want to use the helicopter, they need, or want, to go somewhere in the least amount of time possible. The pilot must expedite

the trip, since direct, speedy transportation is the justification for the company using the helicopter in the first place.

3.7.4 Mission Value

The benefits from mission success are realized by the corporation which operates the helicopter. The relative value of the trip is average since the transport of personnel or property can usually be done with alternate slower modes of transportation if necessary.

3.7.5 Operating Constraints

One of the biggest complaints that corporate/executive helicopter operators have is the lack of available heliports. They would prefer to have heliports as close to their final destinations as possible. They believe the lack of public-use, urban, and corporate heliports constrains the effectiveness of the helicopter for this mission, since it limits the direct flight capability of the helicopter and costs them time.

There are also complaints concerning IFR operations in the Northeast Corridor. Operators complain of the lack of access to established routes, excessive ATC delays, and lack of air traffic controller familiarity with helicopter capabilities. These operational problems result in the helicopter being forced to "fly like a fixed-wing" aircraft when it is not necessary or desirable. These factors limit the effectiveness of helicopter transportation for the corporate/executive mission.

3.8 SCHEDULED COMMUTER

3.8.1 Mission Purpose

Scheduled commuter missions are regularly scheduled operations which are essentially "air carrier" operations. However, under Special Federal Aviation Regulation (SFAR) 38-2, rotorcraft used for scheduled commuters operate under 14 CFR Part 135, not 14 CFR Part 127. Scheduled commuters provide a service to the community by offering a reliable means of transport between international airports and major business centers without the delays normally associated with commuting in and around major metropolitan areas. These operations provide a service whose value is realized primarily by the business community. Scheduled commuter operations are expected to increase as ground transportation congestion worsens in urban areas.

Helicopters and vertical takeoff aircraft such as the tiltrotor and tiltwing, are envisioned to provide a viable alternative to fixed-wing scheduled commuters in many locations. As fixed-wing commuters encounter increasing delays and reduced access to heavily congested airports, vertical takeoff and landing commuter aircraft will become attractive for short and medium distance transport. The number of city center heliports/vertiports are also anticipated to increase. This is expected to reduce travel time between cities and to enhance the vertical takeoff and landing aircraft's economic competitiveness.

3.8.2 Capability

Since the primary purpose of this mission is to provide a faster alternative to ground transportation, scheduled commuters operate primarily in heavily populated and congested metropolitan areas that coincide with strictly controlled airspace. Currently, three major population centers, Boston, New York, and Los Angeles are served by scheduled commuters. Atlantic City, NJ with a population of only 300,000 is the only standard metropolitan statistical area with a population less than 3 million currently served by a scheduled commuter. The reason for the commuter service to Atlantic City is that the gambling casinos generate a demand for transportation to and from New York City. Scheduled commuter flights are flown typically below 2,000 feet above ground level (AGL) and generally do not mix with fixed-wing traffic except when operating near airports. Because these missions are primarily flown to the same destinations each day, routes have been established through formal or informal agreements with controlling ATC facilities.

There are three scheduled commuter helicopter operations currently active in the United States. New York Helicopters serves the New York area and Digital Equipment Corporation (DEC) serves the Boston metropolitan area. Although DEC provides service to corporate employees and customers only, it has been incorporated into the scheduled commuter mission for the purpose of this study because of the number and regularity of its flights. Helitrans Air Service provides service in the Los Angeles area. Of the three operators supporting scheduled commuter operations, none fly IFR with any regularity. New York Helicopters and Helitrans Air Service do not use IFR-certificated rotorcraft for their scheduled commuter operations, and only one DEC helicopter is IFR-certificated.

Two of the three scheduled commuter operations are based at airports, while New York Helicopters is based at a heliport. While scheduled commuters operate from sites varying from small, privately-owned heliports in outlying urban areas to international airports, all of their base facilities are full service facilities providing refueling and maintenance capabilities.

3.8.3 Time Constraints

Time is the critical constraint affecting the success of a scheduled commuter operation. The ability of the commuter to adhere to a schedule is paramount to its operation. Scheduled commuters operate in major metropolitan areas principally as an alternative to ground transportation. Their ability to significantly reduce the amount of time required to travel in and around congested areas is the operation's primary attraction to their customer, the business community. The business community exists in a highly competitive, time-constrained environment and relies on the scheduled commuter to help them avoid delays associated with traveling within major city centers.

3.8.4 Mission Value

The value of the mission, when compared to some of the other missions in the study, can be classified as above average. Similar in purpose to corporate/executive transport, the scheduled commuter provides an alternate

mode of transportation to the business community. However, the ability of the operators to remain in business depends upon their ability to maintain a reliable schedule. An inability to achieve this goal hampers the business community's ability to meet their obligations and in turn forces them to use an alternate, although slower, means of transportation.

3.8.5 Operating Constraints

Constraints for this mission hinge on the fact that as a scheduled operator, the helicopters should ideally be able to operate in all weather and flight conditions. Currently, however, this is not the case. Often schedules are adversely impacted by inclement weather conditions. Constraints in the current IFR infrastructure are also a limiting factor which may make it difficult to maintain regular schedules. In addition, since scheduled commuter flights are performed in the congested and controlled airspace of the Northeast and Southern California, flights sometimes experience delays due to heavy traffic and ATC system constraints.

4.0 SITE SELECTION

In order to determine the sites most likely to benefit from additional low altitude CNS, every county (or equivalent political jurisdiction) in CONUS and Alaska was ranked numerically according to a mathematical formula. This formula took into account both the number of helicopters based in the county and the percentage of time the weather was below typical helicopter VFR minimums. Minimums of 500 feet ceiling and 1 mile visibility (500/1) were used in this analysis. Where appropriate, the formula was adjusted for such factors as human population, annual number of EMS missions, mountainous operating areas, and elimination of nonsignificant helicopters, such as military helicopters, from consideration. The reasons for using these selection criteria are discussed in section 5.0, Area Selection, of the first report (reference 10). The counties with the highest numerical rank were then selected for this study. A total of 50 sites were selected. Figure 2 shows the geographic location of the 48 selected sites within the contiguous United States, and figure 3 shows the 2 selected sites in Alaska. These sites will be the basis for the benefit/cost analyses to be conducted in later tasks.

4.1 METHODOLOGY

Data from FAA Form 5010, the Airport Master Record, which provides information on the number of helicopters based at airports and heliports, was obtained from the FAA National Flight Data Center (NFDC) airports file dated January 1989. By linking the airports file with a database of all the counties and zip codes in the United States, the county where each airport and heliport is located was determined. Using this approach, the total number of helicopters based in each county was determined. Weather data was obtained from the Airport Specific File, developed for the FAA Office of Aviation Policy and Plans. This file provides information on the percentage of time the weather at specific airports exceeds various weather minimums. One airport in each county was chosen at random and its weather data was used for the entire county. Weather data for counties with no airports was interpolated from the closest airport. Each county in the United States was then given a numerical ranking by translating the two sets of data into a formula. The rank was determined by multiplying the number of helicopters based in a county by the percentage of time the weather minimums were below 500 feet and 1 mile. For example, Brazoria, TX had an index of 252 which was derived from the product of 74 based helicopters and 3.4 percent weather below VFR minimums (74 x 3.4 = 252). Counties which had no helicopters were eliminated from the database. Areas with a large number of based helicopters but exceptionally good weather were assigned a low index by this method. For example, Florida and Arizona both had several counties with a large number of helicopters, but they were given a low index because of the low percentage of time that weather was below VFR minimums (less than 0.1 percent in Arizona).

The counties were then divided into three groups: high rank, for indices higher than 100; middle rank, for indices between 50 and 100; and low rank, for indices less than 50 but greater than 0. There were 19 counties with a high ranking, 32 counties with a middle ranking, and 939 counties with a low ranking.

FIGURE 2 SELECTED COUNTY SITES - CONUS

FIGURE 3 SELECTED SITES - ALASKA

4.2 SELECTION CRITERIA

Five primary criteria were used in the selection of the 50 sites for further evaluation. These criteria are: 1) high or medium rank, 2) population density, 3) pertinent missions, 4) number of EMS transports, and 5) mountains. These criteria are explained in the following paragraphs.

The results of the selection process are presented in table 2. The first criterion for site selection was the counties ranking. As can be seen, most of the areas with either a high or a middle ranking were selected for this study. However, several "sanity checks" were performed on the ranked listing in order to further refine it. Since one purpose of this study is to develop a benefit/cost methodology which can be used for any area of the country, some areas were included which had a low rank. The purpose of leaving these low rank counties in the final list is to test the benefit/cost methodology. It is anticipated that a low rank should correlate to a low benefit/cost ratio.

Some of the areas that had a high rank did not make intuitive sense. Therefore, a series of telephone interviews was conducted with known operators in those areas. In many cases it was found that most of the helicopters in such an area were either: 1) military, 2) used only for forestry or fish spotting, or 3) only registered in the county and not actually based there. This procedure identified 23 counties in the high and middle ranked sites that were not significant for purposes of this study. For example, Vernon county, LA had a rank of 452. This was by far the highest rank of any county in the U.S. However, no helicopter operator except for the U.S. Army at Fort Polk could be identified in the county. All 23 of these counties were eliminated from consideration for selection. Table 3 contains a listing of the absolute ranking of all counties in the United States considered in the selection process and the reasons for their exclusion if they had a high or middle rank.

Because helicopters tend to be located in populated areas, the second criterion to be considered was the population of the counties and their surrounding areas. All cities in the United States with a population greater than 2.2 million in their standard metropolitan statistical areas (SMSAs) were selected for consideration in this study. This resulted in the addition of 9 counties to the list. These counties contain the following cities: Atlanta, Baltimore, Chicago, Dallas, Detroit, Houston, Philadelphia, St. Louis and Washington, D.C. It is interesting to note that the selected counties contain the 15 largest standard metropolitan statistical areas in the United States. These 15 areas alone contain 56.7 million people, or 31.3 percent of the United States population.

The third criterion for site selection was the type of missions operating in an area. In the selected counties, it is important to include those missions that have been determined significant for this study. Locational data about those helicopter missions was obtained from the Helicopter Foundation International (HFI) Survey (reference 15), completed in 1988, and from the Helicopter Association International (HAI) 1990 Helicopter Annual (reference 16). The missions of interest are shown in tables 2 and 3. In the tables, a "Y" indicates that the mission is performed in the county. An "N"

TABLE 2
COUNTIES SELECTED FOR LOW ALTITUDE IFR BENEFITS STUDY

RANK	ST	COUNTY	EMS	SAR	OFF-SHORE	CORP/BUSIN	COM-MUTER	AIR TAXI	BASED HELOS	COMMENTS
252	TX	BRAZORIA	Y	N	Y	N	N	Y	74	HIGH INDEX/MULTI MIS
246	CA	LOS ANGELES	Y	Y	N	N	Y	Y	158	HIGH INDEX/MULTI MIS
208	LA	VERMILION	N	N	Y	N	N	N	56	HIGH INDEX
206	CA	SAN BERNARDINO	Y	N	N	Y	N	Y	69	HIGH INDEX/MULTI MIS
168	LA	ORLEANS	Y	Y	Y	Y	N	Y	64	HIGH INDEX/MULTI MIS
164	TX	JEFFERSON	Y	N	Y	Y	N	Y	47	HIGH INDEX/MULTI MIS
155	CA	ALAMEDA	Y	N	N	Y	N	Y	47	HIGH INDEX/MULTI MIS
149	LA	CAMERON	N	N	Y	N	N	N	38	HIGH INDEX
117	LA	JEFFERSON	Y	N	Y	N	N	N	37	HIGH INDEX
107	GA	GWINNETT	Y	N	N	N	N	Y	23	HIGH INDEX/NEAR ATLANTA
98	NJ	HUDSON	Y	N	N	Y	N	N	22	MID INDEX/NYC GROUP
89	LA	IBERIA	N	N	Y	N	N	N	94	MID INDEX/GULF GROUP
88	AK	BARROW	Y	Y	Y	N	N	N	12	MID INDEX/MULTI MIS
86	NY	SUFFOLK	Y	N	N	Y	Y	Y	26	MID/MULTI MIS/NYC GROUP
83	AK	ANCHORAGE	Y	N	Y	N	N	Y	55	MID INDEX/MULTI MIS
81	NJ	UNION	Y	N	N	Y	N	N	18	MID INDEX/NYC GROUP
77	CA	RIVERSIDE	Y	N	N	Y	N	Y	48	MID/MULTI/SCAL GROUP
77	MA	ESSEX	Y	N	N	N	N	Y	10	MID INDEX/BOSTON
68	NH	HILLSBOROUGH	N	N	N	Y	N	Y	16	MID INDEX/BOSTON
64	NY	NEW YORK	Y	Y	N	Y	Y	Y	13	MID INDEX/MULTI MIS/NYC
63	NH	ROCKINGHAM	N	N	N	Y	N	Y	9	MID INDEX/BOSTON
62	MA	MIDDLESEX	N	N	N	Y	N	Y	16	MID INDEX/BOSTON
61	MI	WAYNE	Y	N	N	N	N	N	37	MID INDEX/DETROIT
59	LA	ST MARY	N	N	Y	N	N	N	94	MID INDEX/GULF GROUP
59	NY	WESTCHESTER	Y	N	N	Y	N	N	16	MID INDEX/NYC GROUP
57	CA	SAN DIEGO	Y	Y	N	Y	N	N	83	MID/MULTI/SCAL GROUP
57	NY	ROCKLAND	N	N	N	Y	N	N	12	MID INDEX/NYC GROUP
55	UT	UTAH	Y	N	N	N	N	Y	100	HIGH INDEX/MOUNTAINS
54	MA	HAMPDEN	Y	N	N	Y	N	N	7	MID INDEX/BOSTON
53	LA	LAFAYETTE	Y	N	Y	Y	N	Y	28	MID/MULTI/GULF GROUP
47	MA	SUFFOLK	Y	N	N	N	N	N	6	LOW INDEX/BOSTON
45	NJ	ATLANTIC	N	N	N	N	Y	Y	25	LOW INDEX/COMMUTER
41	LA	TERREBONNE	Y	N	Y	N	N	N	62	MID/OFFS & EMS/GULF GROUP
41	TX	GALVESTON	Y	N	Y	N	N	N	51	LOW INDEX/GULF GROUP
41	WA	KING	Y	N	N	Y	N	Y	45	LOW INDEX/SEATTLE
35	GA	FULTON	Y	N	N	Y	N	Y	31	LOW INDEX/ATLANTA
34	PA	PHILADELPHIA	Y	N	N	N	N	Y	27	LOW INDEX/PHILADELPHIA
34	PA	ALLEGHENY	Y	N	N	Y	N	Y	18	LOW INDEX/PITTSBURGH
32	TX	HARRIS	Y	N	Y	Y	N	Y	170	LOW INDEX/HOUSTON
29	NY	NASSAU	N	Y	N	Y	N	Y	30	LOW INDEX/NYC GROUP
24	NJ	MORRIS	N	N	N	Y	N	N	23	LOW INDEX/NYC GROUP
22	NJ	MIDDLESEX	Y	N	N	N	Y	N	5	COMMUTER BASE/NYC GROUP
21	IL	COOK	N	N	N	Y	N	Y	44	LOW INDEX/CHICAGO
20	TX	DALLAS	Y	N	N	Y	N	N	60	LOW INDEX/DALLAS
16	IN	MARION	Y	N	N	Y	N	Y	34	LOW INDEX/INDIANAPOLIS
13	MD	BALTIMORE	Y	N	N	Y	N	Y	37	LOW INDEX/WASH GROUP
11	MO	ST LOUIS	Y	N	N	Y	N	Y	41	LOW INDEX/ST LOUIS
10	DC	WASHINGTON	Y	N	N	N	N	N	3	LOW INDEX/WASH DC
10	NJ	ESSEX	N	N	N	Y	N	N	7	LOW INDEX/NYC
6	CO	DENVER	Y	N	N	Y	N	N	7	LOW INDEX/DENVER

Y = Mission Performed   N = Mission not Verified

TABLE 3
RELATIVE RANKING OF COUNTIES CONDIDERED FOR LOW ALTITUDE IFR BENEFITS STUDY

RANK	ST	COUNTY	EMS	SAR	OFF-SHORE	CORP/BUSIN	COM-MUTER	AIR TAXI	BASED HELOS	STUDY SELECT*	COMMENTS
452	LA	VERNON	N	N	N	N	N	N	120	N	MILITARY
276	WA	WHATCOM	N	N	N	N	N	N	108	N	FISHING/FORESTRY
261	ME	PENOBSCOT	N	N	N	N	N	N	36	N	FORESTRY
252	TX	BRAZORIA	Y	N	Y	N	N	Y	74	Y	HIGH INDEX/MULTI MIS
246	CA	LOS ANGELES	Y	Y	N	N	Y	Y	158	Y	HIGH INDEX/MULTI MIS
208	LA	VERMILION	N	N	Y	N	N	N	56	Y	HIGH INDEX
206	CA	SAN BERNARDINO	Y	N	N	Y	N	Y	69	Y	HIGH INDEX/MULTI MIS
194	SC	RICHLAND	N	N	N	Y	N	Y	52	N	HIGH INDEX/MILITARY
190	OR	MARION	Y	N	N	Y	N	Y	47	N	HIGH INDEX/AGRIGULTURE
169	IN	SHELBY	Y	N	N	Y	N	Y	49	N	INDIANAPOLIS SELECTED
168	LA	ORLEANS	Y	Y	Y	Y	N	Y	64	Y	HIGH INDEX/MULTI MIS
164	TX	JEFFERSON	Y	N	Y	Y	N	Y	47	Y	HIGH INDEX/MULTI MIS
155	CA	ALAMEDA	Y	N	N	Y	N	Y	47	Y	HIGH INDEX/MULTI MIS
149	LA	CAMERON	N	N	Y	N	N	N	38	Y	HIGH INDEX
149	OR	YAMHILL	N	N	N	N	N	N	37	N	EVERGREEN HELICOPTER
117	LA	JEFFERSON	Y	N	Y	N	N	N	37	Y	HIGH INDEX
112	LA	PLAQUEMINES	N	N	Y	N	N	N	39	N	OFFSHORE ONLY
107	GA	GWINNETT	Y	N	N	N	N	Y	23	Y	HIGH INDEX/NEAR ATLANTA
107	IA	BLACKHAWK	N	N	N	N	N	Y	29	N	MILITARY
98	NJ	HUDSON	Y	N	N	Y	N	N	22	Y	MIDDLE INDEX/NYC GROUP
95	PA	ADAMS	N	N	N	N	N	Y	24	N	MIDDLE INDEX/AGRIGULTURE
89	LA	IBERIA	N	N	Y	N	N	N	94	Y	MIDDLE INDEX/GULF GROUP
88	AK	BARROW	Y	Y	Y	N	N	N	12	Y	MID INDEX/MULTI MIS
86	NY	SUFFOLK	Y	N	N	Y	Y	Y	26	Y	MID INDEX/MULTI MIS/NYC GROUP
85	ID	NEZ PERCE	N	N	N	N	N	Y	16	N	MID INDEX/FORESTRY
83	AK	ANCHORAGE	Y	N	Y	N	N	Y	55	Y	MIDDLE INDEX/MULTI MIS
81	NJ	UNION	Y	N	N	Y	N	N	18	Y	MIDDLE INDEX/NYC GROUP
78	RI	WASHINGTON	N	N	N	N	N	Y	65	N	MIDDLE INDEX/MILITARY
77	CA	RIVERSIDE	Y	N	N	Y	N	Y	48	Y	MID INDEX/MULTI MIS/SCAL GROUP
77	MA	ESSEX	Y	N	N	N	N	Y	10	Y	MID INDEX/BOSTON
75	NJ	MONMOUTH	N	N	N	N	N	Y	17	N	MIDDLE INDEX/MILITARY
68	NH	HILLSBOROUGH	N	N	N	Y	N	Y	16	Y	MID INDEX/BOSTON
66	KY	FRANKLIN	N	N	N	N	N	N	44	N	MID INDEX/MILITARY
64	NY	NEW YORK	Y	Y	N	Y	Y	Y	13	Y	MID INDEX/MULTI MIS/NYC
63	NH	ROCKINGHAM	N	N	N	Y	N	Y	9	Y	MID INDEX/BOSTON
62	MA	MIDDLESEX	N	N	N	Y	N	Y	16	Y	MID INDEX/BOSTON
61	MI	WAYNE	Y	N	N	N	N	N	37	Y	MID INDEX/DETROIT
61	CA	KERN	N	N	N	Y	N	N	29	N	MID INDEX/MILITARY

Y = Mission Performed N = Mission not Verified

* "Y" Indicates County Selected for Study

TABLE 3
RELATIVE RANKING OF COUNTIES CONDIDERED FOR LOW ALTITUDE IFR BENEFITS STUDY (Continued)

RANK	ST	COUNTY	EMS	SAR	OFF-SHORE	CORP/BUSIN	COM-MUTER	AIR TAXI	BASED HELOS	STUDY SELECT*	COMMENTS
59	LA	ST MARY	N	N	Y	N	N	N	94	Y	MID INDEX/GULF GROUP
59	NY	WESTCHESTER	Y	N	N	Y	N	N	16	Y	MIDDLE INDEX/NYC GROUP
57	CA	SAN DIEGO	Y	Y	N	Y	N	N	83	Y	MID INDEX/MULTI MIS/SCAL GROUP
57	AL	MOBILE	Y	Y	Y	N	N	Y	31	N	MID INDEX/ISOLATED
57	NY	ROCKLAND	N	N	N	Y	N	N	12	Y	MIDDLE INDEX/NYC GROUP
56	KS	SHAWNEE	Y	N	N	Y	N	Y	27	N	ISOLATED
55	UT	UTAH	Y	N	N	N	N	Y	100	Y	HIGH INDEX/MOUNTAINS
54	MA	HAMPDEN	Y	N	N	Y	N	N	7	Y	MID INDEX/BOSTON
54	NY	TIOGA	N	N	N	N	N	N	10	N	ISOLATED
53	LA	LAFAYETTE	Y	N	Y	Y	N	Y	28	Y	MID INDEX/MULTI MIS/GULF GROUP
53	ME	KENNEBEC	N	N	N	N	N	N	6	N	ISOLATED
52	CA	HUMBOLDT	N	Y	N	N	N	N	4	N	ISOLATED
51	TN	WASHINGTON	N	N	N	N	N	N	16	N	ISOLATED
50	CA	FRESNO	Y	N	N	N	N	Y	27	N	6 AREAS IN REG SEL'D
50	CA	SANTA BARBARA	Y	N	N	N	N	Y	26	N	6 AREAS IN REG SEL'D
49	TN	RUTHERFORD	N	N	N	N	N	N	61	N	ISOLATED/NASHVILLE
47	MA	SUFFOLK	Y	N	N	N	N	N	6	Y	LOW INDEX/BOSTON
45	NJ	ATLANTIC	N	N	N	N	Y	Y	25	Y	LOW INDEX/COMMUTER
45	CA	MONTEREY	Y	N	N	N	N	Y	17	N	6 AREAS IN REG SEL'D
45	AK	KETCHIKAN	Y	N	N	Y	N	Y	26	N	LOW INDEX
44	MA	NORFOLK	N	N	N	N	N	N	19	N	LOW INDEX/BOSTON
42	WA	CHELAN	N	N	N	Y	N	Y	13	N	LOW INDEX/SEATTLE
41	WY	LARAMIE	N	N	N	N	N	N	38	N	MILITARY
41	LA	TERREBONNE	Y	N	Y	N	N	N	62	Y	MID INDEX/OFFS&EMS/GULF GROUP
41	TX	GALVESTON	Y	N	Y	N	N	N	51	Y	LOW INDEX/GULF GROUP
41	WA	KING	Y	N	N	Y	N	Y	45	Y	LOW INDEX/SEATTLE
40	NY	ONEIDA	N	N	N	N	N	N	9	N	ISOLATED
40	PA	FRANKLIN	N	N	N	N	N	N	10	N	LOW INDEX/ISOLATED
39	NY	MONROE	N	N	N	N	N	N	27	N	ISOLATED
38	RI	KENT	N	N	N	Y	N	Y	8	N	LOW INDEX
38	CO	WELD	Y	N	N	N	N	N	20	N	LOW INDEX/DENVER
38	NH	BELKNAP	N	N	N	N	N	N	10	N	ISOLATED
38	NH	CARROLL	N	N	N	N	N	N	6	N	LOW INDEX/ISOLATED
38	CT	TOLLAND	N	N	N	N	N	N	8	N	LOW INDEX/BOS/NYC
37	MA	WORCESTER	N	N	N	N	N	N	19	N	LOW INDEX/REG GROUP
35	NY	ULSTER	N	N	N	N	N	N	8	N	LOW INDEX/ISOLATED
35	GA	FULTON	Y	N	N	Y	N	Y	31	Y	LOW INDEX/ATLANTA
35	CT	FAIRFIELD	N	N	N	N	N	N	15	N	LOW INDEX/REG GROUP
34	PA	PHILADELPHIA	Y	N	N	N	N	Y	27	Y	LOW INDEX/PHILADELPHIA
34	PA	ALLEGHENY	Y	N	N	Y	N	Y	18	Y	LOW INDEX/PITTSBURGH
33	KY	FAYETTE	Y	N	N	Y	N	N	11	N	LOW INDEX
33	CA	ORANGE	N	N	N	Y	N	Y	62	N	6 AREAS NEAR SELEC'D
32	TX	HARRIS	Y	N	Y	Y	N	Y	170	Y	LOW INDEX/HOUSTON

Y = Mission Performed N = Mission not Verified

* "Y" Indicates County Selected for Study

TABLE 3
RELATIVE RANKING OF COUNTIES CONDIDERED FOR LOW ALTITUDE IFR BENEFITS STUDY (Continued)

RANK	ST	COUNTY	EMS	SAR	OFF-SHORE	CORP/BUSIN	COM-MUTER	AIR TAXI	BASED HELOS	STUDY SELECT*	COMMENTS
29	NY	NASSAU	N	Y	N	Y	N	Y	30	Y	LOW INDEX/NYC GROUP
24	NJ	MORRIS	N	N	N	Y	N	N	23	Y	LOW INDEX/NYC GROUP
23	MD	PRINCE GEORGES	Y	N	N	N	N	N	7	N	LOW INDEX/REG GROUP
23	PA	CHESTER	Y	N	N	Y	N	Y	30	N	LOW INDEX/NEAR PHILADELPHIA
22	NJ	MIDDLESEX	Y	N	N	N	Y	N	5	Y	COMMUTER BASE/NYC GROUP
22	VA	PRINCE WILLIAM	N	N	N	N	N	Y	5	N	LOW INDEX/REG GROUP
21	IL	COOK	N	N	N	Y	N	Y	44	Y	LOW INDEX/CHICAGO
20	TX	DALLAS	Y	N	N	Y	N	N	60	Y	LOW INDEX/DALLAS
16	IN	MARION	Y	N	N	Y	N	Y	34	Y	LOW INDEX/INDIANAPOLIS
13	MD	BALTIMORE	Y	N	N	Y	N	Y	37	Y	LOW INDEX/WASH GROUP
12	VA	FAIRFAX	Y	N	N	N	N	Y	3	N	LOW INDEX/REG GROUP
12	MD	FREDERICK	Y	N	N	N	N	N	8	N	LOW INDEX/REG GROUP
11	MO	ST LOUIS	Y	N	N	Y	N	Y	41	Y	LOW INDEX/ST LOUIS
10	MD	ANNE ARUNDEL	N	N	N	N	N	N	3	N	LOW INDEX/REG GROUP
10	DC	WASHINGTON	Y	N	N	N	N	N	3	Y	LOW INDEX/WASH DC
10	NJ	ESSEX	N	N	N	Y	N	N	7	Y	LOW INDEX/NYC GROUP
6	CO	DENVER	Y	N	N	Y	N	N	7	Y	LOW INDEX/DENVER

Y = Mission Performed N = Mission not Verified

* "Y" Indicates County Selected for Study

means that it was not possible to determine whether the mission was performed in the county. Any county with three or more of the significant missions operating within its borders was selected as a site for this study.

The data on the distribution of missions of interest corroborates the conclusions drawn in the first report for this task, which are that: 1) EMS operations are found in almost every part of the United States, in urban, suburban and rural settings, and 2) the corporate/executive/business and air taxi missions are also found throughout the country but tend to be concentrated in the northeastern United States, the northwestern United States, southern California, and Florida.

A fourth criterion for site selection was the number of EMS transports performed in each area, because of the high value associated with saving a human life. According to the May 1990 issue of the <u>Journal of Air Medical Transport</u>, 5 of the top 10 cities in the United States for annual EMS transports are included in the cities selected for this study. They are: Pittsburgh, PA; Baltimore, MD; Dallas, TX; Denver, CO; and Philadelphia, PA. Of the five cities not included, two were excluded because of their extremely good weather (Phoenix, AZ and Tulsa, OK) and three were excluded for having operating areas similar to other areas selected and a low rank in the index (Cleveland, OH; Durham, NC; and Memphis, TN).

In order to evaluate operational conditions in all parts of the United States, it is important to investigate areas that may have unique or unusual problems with regard to helicopter operations. Therefore, the final consideration used in selecting counties for this study was the presence of mountains. At least three counties, Utah County, UT (Salt Lake City); Denver County, CO; and King County, WA (Seattle) were selected specifically for their mountainous terrain. Two additional counties are known to have mountainous terrain in their areas of operation (Allegeny County, PA and Riverside County, CA) but were selected based on the criteria already discussed.

5.0 OPERATIONAL CONSTRAINTS

5.1 OPERATOR INTERVIEWS

Telephone discussions were conducted with helicopter operators in the 50 selected counties to identify the operating characteristics and constraints of the helicopter operators who fly within these areas. Where possible, representatives of each of the seven missions considered in this report were contacted in each area selected. However, some missions are not performed in all areas. For instance, the offshore mission is only conducted along the Gulf of Mexico and in Alaska; SAR is most often found in rural and coastal areas; and at the present time, scheduled commuters are located in New York City, the Boston metropolitan area, and Los Angeles (although at various times they have been located in other major cities, most notably Chicago and San Francisco).

Each operator was asked questions regarding the number and types of helicopters operated, the types of missions performed, number of annual operations, types of operating constraints encountered, and the need for more or different CNS services. A sample operator data sheet is shown in figure 4.

The results are discussed in the following sections by mission. Many of the constraints encountered are experienced by all types of operators in all locations. Any specific constraints found on a regional or local basis are described in detail in the following paragraphs.

5.2 EMERGENCY MEDICAL SERVICE (EMS)

The EMS mission is performed in many areas throughout the United States. In fact, many areas of the United States are served by more than one EMS operator. The helicopters are primarily privately owned, either by a helicopter service company or directly by the hospital. However, there are also a few public-service operators, such as state police and local police/fire departments, providing EMS. The private helicopters are operated under 14 CFR Part 135. Public service helicopters are generally operated in accordance with 14 CFR Part 91, which is less restrictive in terms of aircraft and aircrew certification requirements, and VFR/IFR operating limitations.

5.2.1 Mission Characteristics

Helicopters used for EMS transport tend to be twin-engine turbines. According to the July 1989 issue of Hospital Aviation, 68 percent of all EMS helicopters are twin-engine turbines. The percentage of twin-turbine machines used for EMS has been steadily increasing for the last 5 years, and includes the following models: the MBB BK-117 and BO-105; the Aerospatiale AS 355 (Twin Star) and SA360 (Dauphin); Bell 212 and 222; Agusta 109; and the Sikorsky S-76. The other 32 percent of EMS helicopters are single engine turbines, and include the following models: the Bell B206L-3 (Long Ranger) and B206B-B3 (Jet Ranger), and the Aerospatiale AStar and Alouette.

The typical EMS operator maintains one or two aircraft at each base of operations. Some public service operators, like the Maryland State Police,

County ____________

OPERATOR DISCUSSION TOPICS

Company ________________ Contact ____________ Phone __________

1. Location of based aircraft ____________________

2. How many and what type of helicopters does your company operate?

Type	Number

3. a) What are the types of missions that you fly? b) What percentage of your aircraft are used for each mission? c) What is the average number of crew and passengers carried for each mission?

Missions	Percent	Passengers/ Crew

4. a) How many operations (a takeoff OR a landing) do your helicopters fly annually? ___________

   b) Is there any seasonal (winter/summer etc.) in the number of operations?

5. a) How many of your helicopters are IFR equipped? _____________

   b) How many pilots are IFR rated? ___________

   c) What percent of the missions you fly are flown IFR?

Missions	Percentage

   d) If you don't fly IFR what is/are the reason(s)?

1

6. a) What are your primary origins and destinations? b) What is your most common en route altitude (per route)? c) Why (how was it determined)?

Origin	Destination	Altitude

7. a) How were your most commonly flown routes determined? b) What type of landmarks, or guidance do you use to follow the route?

8. What types of delays do you encounter due to the routes you must follow? (Control Zones, TCA, etc.)

9. At what point do you stop flying VFR/SVFR? (minimums)

day ____________
night ____________
local ____________
X/C ____________
other ____________

Comments:

2

FIGURE 4 OPERATOR DISCUSSION TOPICS

10. In what other ways does weather constrain your flights?

11. a) How many operations are delayed or missed due to procedural (ATC) constraints? b) How long is the average delay? c) What types of constraints do you encounter?

Delayed ________ Missed _______ Average Time ________

Types of Constraints:

12. a) What is the extent of the radar coverage in your operational area? b) Do you feel the coverage is adequate for your purposes or would you like to see more extensive coverage?

13. a) What is the extent of the communications in your operational area? b) Do you feel the coverage is adequate for your purposes or would you like to see more extensive coverage?

14. a) Do you expect your business to increase or decrease within the next year? b) Do you expect a different increase or decrease among the different missions you perform?

15. a) Do you expect to use more aircraft (purchased or leased) within the next year? b) Do you expect a different increase or decrease among the different missions you perform?

16. a) If additional IFR infrastructure were available would you fly IFR more frequently? b) If not why not? c) Would you buy/lease an IFR certified helicopter? d) If not why not?

17. Are there any missions you don't now perform that you would perform if you had better CNS services?

18. a) Would you perform more operations in you current missions if you had better CNS services? b) If not why not?

FIGURE 4 OPERATOR DISCUSSION TOPICS (Continued)

and some helicopter service companies, like Rocky Mountain Helicopters and Petroleum Helicopters, Inc., have quite large EMS helicopter fleets. However, there are usually only one or two helicopters located in each area of operation. Most of the operators have partially IFR-equipped, but not necessarily IFR-certificated, helicopters. A large majority of the EMS operators interviewed had at least one IFR-equipped helicopter. However, very few reported that they routinely accepted flights into known IFR conditions. Most of the operators use their IFR-equipped helicopters only to increase their margin of safety in the event of encountering deteriorating weather conditions. Almost all EMS operators require their pilots to be IFR-rated and current.

Discussions on the operational scenarios available to the EMS pilots addressed VFR, Special VFR (SVFR), and IFR operations. VFR allows EMS operators to fly direct and/or discrete routes from one hospital to another. A LORAN receiver is usually used for direct, point-to-point navigation, and helicopter routes with discrete landmarks are usually used for ground-referenced navigation. Direct navigation is used when possible, because it allows for the shortest flight time and therefore reduces operating costs. However, where discrete helicopter routes exist, it is usually in response to a need to safely handle a large number of helicopter operations in the area and to avoid fixed-wing traffic in the vicinity of busy airports. (An additional advantage of discrete routes is that they usually are placed in areas of high ambient noise, helping to contribute to a "Fly Neighborly" program.) EMS operators interviewed felt that the discrete routes provided them with a valuable safety advantage in that they knew where the other helicopter traffic was going to be, while not penalizing them significantly with increased flight time. The majority of operators interviewed accepted only VFR missions.

SVFR allows EMS operators to traverse or land at destinations within a control zone in IMC. EMS pilots feel that flying SVFR saves trip time and enhances mission success compared to the alternative of flying IFR. Most operators use specific routes established by letters of agreement to fly into and out of control zones. EMS pilots cited these routes as being particularly important during SVFR, since flight safety is enhanced and their comfort level is increased.

IFR missions are routinely accepted by only a small percentage of EMS operators. Even the operators who do fly IFR missions do so very infrequently. One of the operators estimated he flew IFR 20 percent of the time and two others estimated they flew IFR 10 percent of the time. These figures, however, show an increase over past years. The percentage of EMS operations conducted IFR is climbing, and it is anticipated that it will continue to do so.

There are several factors which discourage EMS operators from flying IFR. Regulation 14 CFR Part 135.221 (requiring the pilot to identify an alternate airport with acceptable weather conditions) and regulation 135.223 (requiring enough fuel on board to fly to the alternate and loiter there for one half hour) tend to discourage EMS operators. Their maximum flight time may be as short as 2 to 2 1/2 hours when carrying a medical crew and medical equipment.

The closest acceptable alternate airport may be one half hour or more away. Thus, EMS operators may lose up to one-half of usable flight time if an IFR flight plan is filed. The requirement to carry extra fuel can also create a weight penalty that can mean the elimination of critical medical personnel or equipment from the trip. Several operators also mentioned the availability of fixed-wing aircraft as a lower cost option than the helicopter when weather conditions are such that only airport-to-airport flights are possible. The high cost of avionics, especially the autopilot and flight director, and the pilot training requirements for IFR flight were cited as prohibitive by one operator that did not currently have IFR capability.

Furthermore, the EMS operator's quick response time when flying VFR as compared with the 15 or 20 minutes it would take the pilot to prepare and file an IFR flight plan was cited as another reason for the reluctance to fly IFR.

Of the operators interviewed, the average helicopter performed 2,465 operations (a takeoff or a landing) per year. This figure includes operations for maintenance and refueling.

5.2.2 Flight Characteristics

Inter-hospital missions for EMS helicopters typically originate at the sponsoring hospital. Often they will provide service to any hospital or heliport/airport within their operational area. The average VFR altitude flown en route in the interviews conducted for this study was 1,140 feet AGL.

Table 4 provides recommended VFR operating minimums for EMS operators as stated in Advisory Circular 135-14A. The typical EMS operator has two operational areas, local and cross country. The local area is usually restricted to approximately a 30 nm radius from the hospital during the day and areas which are well lighted at night. The cross-country area extends from the local area out to a radius of 60 to 150 nautical miles. The operator's VFR weather minimums are usually lower when the flight will take place in the local operating area, i.e., familiar territory. Company weather minimum and local/cross country operating areas are covered in detail in table 6 of section 8.1.1.

TABLE 4 AC135-14A SUGGESTED EMS VFR OPERATING MINIMUMS

Conditions:	Day/ Local	Day/Cross Country	Night/ Local	Night/Cross Country
Ceiling (Ft)	500	1,000	800	1,000
Visibility (Nm)	1	1	2	3

Most EMS operators use LORAN navigation for direct routings from one hospital to another. Only one operator, in Denver, CO, reported navigating primarily with very high frequency omni-directional range (VOR), due to the unavailability of the LORAN signal. (Two additional chains of LORAN transmitters were installed in late 1990. These chains filled the

coverage gap.) Ground-referenced navigation is also frequently used for flights along either published helicopter routes or SVFR routes described in letters of agreement with ATC facilities.

5.2.3 Operational Constraints

5.2.3.1 ATC Procedures

Only 2 EMS operators of 14 interviewed reported any delays associated with ATC procedures. One reported two delays last winter for 1 minute each at Denver Stapleton Airport during IFR conditions. This problem could have been eliminated by simultaneous approaches, according to the operator. The other delay involved the Boise, ID, airport radar service area (ARSA) during times when the field was IFR. The operator interviewed felt that approximately 2 or 3 percent of winter operations were delayed for 3 or 4 minutes. Again, it was felt that the problem could have been eliminated with simultaneous approaches and diverging departures.

An operator in the Northwest reported that local air traffic controllers there do not understand the point-in-space approach for helicopters. An operator in the South reported that it was sometimes difficult to get into controlled airspace during IMC, but that the "Lifeguard" call sign that gives EMS flights priority always worked. He also said that in most cases, if the mission could not be done under VFR, the weather conditions were zero/zero and even IFR capability would not help.

All EMS operators felt their working relationships with air traffic controllers to be excellent. Most said they never had to use the "Lifeguard" call sign, since the handling they received was so good. Even in a crowded ATC environment like New York, one operator interviewed reported having to use the "Lifeguard" call sign only three times in 2 years. Several operators also stated that they had ATC priority all of the time due to their EMS mission.

In the Northeast one operator reported that at one airport both the helicopter controller and the radio frequency that helicopters use are too busy. He commented that it was impossible "to get a word in edgewise." It was his belief that a separate helicopter frequency and a separate helicopter controller at this facility were necessary.

5.2.3.2 Radar Coverage

All of the operators interviewed felt that radar coverage in their areas was adequate to perform the EMS mission. However, there were a few comments about where improvements could be made.

In Seattle, WA, an operator reported that in order to be covered by radar over Puget Sound, he was forced to fly at 4,000 feet. However, in the winter months, this was often not possible without encountering icing conditions at that altitude.

5.2.3.3 <u>Communications Coverage</u>

All of the operators interviewed expressed satisfaction with communications coverage in their areas.

5.2.3.4 <u>Current IFR Infrastructure</u>

The only operating constraint mentioned consistently by the EMS operators interviewed was poor weather reporting. Almost half of the operators interviewed mentioned inadequate weather reporting, especially at night, as a problem. The lack of a weather observer in the area of the mission destination often results in the EMS operator refusing a mission rather than taking a risk in marginal weather.

One reason cited for the low percentage of operators flying IFR missions is the lack of precision or nonprecision approaches at most of the hospitals, heliports, and/or local community airports served by EMS operators. Even if there is a nonprecision approach of some sort to a rural destination, sometimes the approach minimums can be higher for an IFR landing than for a VFR or SVFR landing. This means that often an EMS operator can fly VFR to more destinations, especially rural destinations or those in uncontrolled airspace, than if flying IFR. This is significant since many of the inter-hospital transfers are from rural areas to the base hospital, not from an urban area to the base hospital. Most operators indicated that if there were more IFR approaches into their destination hospitals and/or airports, they would probably fly more IFR missions. Without suitably located instrument approaches, EMS pilots believe flying IFR will provide minimal or no benefits.

5.2.3.5 <u>Enhanced IFR Infrastructure</u>

None of the EMS operators interviewed felt that additional CNS services would increase their IFR operations at this time. However, the one thing that generated serious interest was the possibility of LORAN nonprecision approaches to hospitals. All operators felt that nonprecision approaches would make it advantageous to fly IFR more often.

5.3 OFFSHORE

The offshore helicopter mission is performed in two primary areas of the United States. In the Gulf of Mexico and in the Arctic Ocean north of Alaska, extensive offshore oil drilling and production creates a high demand for transportation services uniquely suited to the helicopter. Helicopters are operated by oil companies to provide this service for their own employees under 14 CFR Part 91. In addition, helicopter services are leased to oil companies under 14 CFR Part 135 by private helicopter companies.

All along the Gulf Coast, but particularly in Texas and Louisiana, helicopters are based almost solely for the purpose of performing the offshore mission. In Alaska, too, a predominance of helicopter services go into the offshore mission, although not as large a percentage of helicopters are used solely for that purpose as is the case in the Gulf.

Of prime importance in the offshore mission is the movement of people to, from, and between the rigs. The movement of supplies and equipment also plays an important part in the justification for this mission.

As might be expected, the fate of the offshore helicopter mission is closely tied to the fortunes of the oil business. When the oil industry declines, as it did with the oil glut of the mid-1980's, both the exploration/drilling and production aspects of the industry also decline. As those areas decrease, so does the demand for offshore helicopter service.

After several years of decreased activity, the industry is now apparently on the rebound, and there is considerable optimism among offshore operators that their future will show a steady increase in business. That optimism extends to the probable need for additional helicopters to cope with the demand. In fact, several companies have already received or ordered additional helicopters this year, with plans for further expansion next year.

5.3.1 Mission Characteristics

Many different types of helicopters are used in the offshore mission. They range in size from the small Bell 47G to large tandem-rotor aircraft like the Boeing 234. By far the most common helicopters in use for the offshore mission are the Bell 206B (Jet Ranger) and Bell 206L (Long Ranger), which together make up more than 48 percent of the offshore helicopters. According to a 1989 operations survey performed by the Helicopter Safety Advisory Conference (HSAC), the helicopter fleet size in the Gulf of Mexico is 596, of which 126 or 21.1 percent of the helicopters are IFR-certificated. The IFR-certificated machines carry 50 percent of the passenger load for this mission. Interviews with Alaskan helicopter operators show 25 percent of their helicopters to be certified for IFR flight.

Some offshore operators use a single helicopter to service the offshore area, while the largest operator lists 301 helicopters in its inventory. Only a small percentage of Gulf offshore missions are presently performed using IFR. In Alaska where weather and darkness play a more significant role, the figure is somewhat higher. One large Alaskan company reports that 70 percent of the operations performed by its 61 helicopters are conducted IFR. However, as a rule the percentage of offshore missions performed IFR is relatively small in Alaska, just as in the Gulf.

Many offshore helicopter pilots are IFR-rated, but only a small percentage are current. Since most offshore work is done VFR and in smaller, three to six place helicopters, the majority of missions are performed with one pilot. However, for some IFR missions in large helicopters, two crewmembers are required. Average passenger load, determined by the telephone interviews, is between two and three, although HSAC figures for 1989 for the Gulf show 1.74 passengers per flight.

A wide divergence in operational activity might be expected from operators varying so greatly in size; this proved to be true. One of the smaller operators reported some 19,200 annual operations, while the largest reported 1.3 million operations. Operators in the Gulf region experience about a 20

percent reduction in overall business during the winter months because of deteriorating weather conditions. In contrast, the number of IFR missions in Alaska remains fairly constant throughout the year, while VFR operations drop significantly in the winter.

When asked why more IFR missions are not flown, the most common reason given by operators is that the nature of the flights makes it impractical or simply does not require it. A secondary reason is cost, although most say if their customers required IFR service and were prepared to pay the higher costs of training, equipment, fuel, etc., they would provide the service. Finally, the inefficiency caused by occasional delays, no direct routing and especially the loss of payload (because of the weight of the additional fuel required to meet requirements for alternate landing sites), currently discourages operators from flying IFR.

5.3.2 Flight Characteristics

In the Gulf, offshore missions can originate from virtually all areas along the coast. However, the heaviest concentration of activity and consequently the sites selected for close study all fall in Texas and Louisiana, mostly between the Galveston, TX, area and New Orleans, LA. In Alaska the boroughs most employed in offshore missions are Anchorage and Barrow.

In the Gulf area, there are heavy concentrations of helicopters in the coastal areas around Lake Charles, Lafayette, Morgan City, and Houma in Louisiana. A heavy concentration of service goes to the oil producing areas south of New Orleans, while slightly lighter activity is shown in the western part of the Gulf where there is more gas production. Gulf missions typically are flown from 2 to 150 miles from shore. An average distance is around 80 miles. Another aspect of the mission entails short flights between various rigs in a cluster. Often 80 to 100 takeoffs and landings are made during one such mission. The implications for attempting such complex missions using instrument flight rules are obvious, even if radar and communications services were readily available.

The Prudhoe Bay area of Alaska is the site of most offshore helicopter operations. Helicopter operators are based in the towns of Prudhoe Bay and Deadhorse which are also the staging area for passengers and cargo. Mission distances of up to 150 nautical miles are common although rigs are usually located no further than 20 nautical miles from shore. Pilots generally fly along the coastline towards the rig's vicinity and then proceed directly to the rig.

Helicopter operations were performed in the mid-1980's to oil exploration rigs in the Navarin Basin, located in the Bering Sea approximately 400 miles off the West Coast of Alaska. The support operations provided by Boeing BV234ERs (specially configured with long range fuel tanks) have ceased and are not projected to restart. This site is not considered further in this study.

Altitudes flown, both in the Gulf and in Alaska, depend on the mission profile. Short VFR flights between rigs are typically flown at 500 AGL, while VFR transit flying is generally from 1,000 feet to 2,500 feet AGL. IFR flight is at assigned altitudes, but they range from 2,000 to 6,000 feet, sometimes a little higher. Usually, crews like to keep from getting too high for passenger comfort reasons (ear popping, etc.), but some aircraft are more efficient at the higher, cooler altitudes.

Navigation is accomplished chiefly by dead reckoning/pilotage assisted by LORAN for VFR flight. In Alaska where extensive overland flight is required to place the helicopter in position for offshore work (as is often the case with Anchorage-based aircraft) the route of flight in that sparsely populated area is dictated by availability of fuel. In that area, navigation during IFR flight is accomplished chiefly by LORAN or Omega, while in the Gulf a combination of VOR (as long as the signal holds out) and LORAN is used. Helicopter routes are well established in the Gulf for north-south missions, but the system does not possess the flexibility to allow east-west flight at this time. There are no specific routes established between offshore platforms.

Each company establishes their own VFR weather minimums. Generally, in the Gulf, day VFR minimums are 500 feet and 1 mile. In Alaska, accepted minimums are 300 feet and 1 mile. Night VFR minimums in both locales are typically 1,000 feet and 3 miles, though night operations are not common.

In addition to ceiling and visibility constraints, weather phenomena, such as icing, blowing snow, thunderstorms, and high winds also hinder rotorcraft operations. One important function performed by offshore operators in the Gulf is hurricane evacuation ("Hurrivac"), i.e., the evacuation of workers from oil rigs located in the path of an approaching hurricane. Timing is an important element in this operation, since rig operators want to remain on the rig as long as possible and return as soon as possible after the hurricane. On the other hand, helicopter operators must not wait too long when evacuating personnel or they risk having to shut down a helicopter on a rig, being forced to remain there with the people they were attempting to remove.

5.3.3 Operational Constraints

5.3.3.1 ATC Procedures

The offshore mission operators had no complaints regarding their handling by air traffic control. The primary procedural complaint identified by them involved the necessity of using nonradar IFR separation standards in the Gulf, a problem that is caused by lack of low-level radar coverage in that area (see section 5.3.3.2).

5.3.3.2 Radar Coverage

A majority of the operators commented on the lack of low-level radar coverage in the Gulf. The larger operators saw this as a significant limitation on their operations, since when flying IFR to the rigs they are forced to adhere to nonradar separation standards. Using International Civil

Aviation Organization (ICAO) regulations, 50 miles separation is required south of latitude 28 degrees - 15 minutes north, in contrast to the 5 mile requirement that exists for radar separation. Because of these large IFR separation requirements, the ATC system can't possibly handle a large volume of traffic, and operators are forced to fly VFR for the sake of expediency. An additional problem caused by lack of radar coverage is that no formal east-west IFR routes currently exist, forcing aircraft to operate VFR in inclement weather if they wish to fly in an east-west direction.

In contrast, a number of smaller operators do not feel that the lack of low-level radar coverage constrains their operations. These operators fly VFR nearly all the time and say they would not fly more IFR missions even if the radar coverage were improved.

5.3.3.3 Communications Coverage

Helicopter operations and air traffic controllers identified a number of locations in the Gulf of Mexico with low-altitude communications deficiencies. These deficiencies exist despite the presence of six offshore VHF remote communications air/ground (RCAG) facilities. As a result, IFR helicopter flights routinely incur delays.

One type of delay occurs when an IFR helicopter commences an instrument approach to some offshore sites. If the pilot loses communications with ATC as the helicopter descends below communications line of sight, ATC must prevent other IFR traffic from entering the same airspace. A second type of delay, though currently not as troublesome, occurs when an IFR helicopter travels to the outermost rigs. The IFR helicopter loses communications with ATC and again ATC must prevent other IFR aircraft from flying into the same airspace. This operational delay will become more common when rigs are located further offshore.

Offshore operators in the arctic regions have fewer communications problems. Oil rigs are normally located within 20 miles of shore and land-based RCO's provide adequate coverage for the majority of the helipads.

5.3.3.4 Current IFR Infrastructure

The vast majority of offshore missions are conducted using visual flight rules for several reasons. First, it is more fuel efficient to fly offshore missions VFR. Routes are usually the most direct when using onboard navigation to fly directly to the desired Gulf rig destination. Altitude variation lets the pilot select the optimum altitude for economy and passenger comfort. No delays are experienced either by departing or arriving rotorcraft. Delays or indirect routing cause fuel costs to climb while personnel costs swell with overtime paid to aircrew and to the employees being transported.

Gulf of Mexico IFR operations are also severely hampered by alternate destination requirements. As with any IFR operation, 14 CFR Par 91 requirements dictate that when the destination weather forecast is less than 2,000 feet or 3 miles, an alternate destination is required. OSAPs have

additional alternate requirements, one of which is that alternate destinations have a standard or special instrument approach with minimums of 800 feet and 2 miles. This requirement excludes OSAPs as an alternate. Airborne radar approaches (ARAs), a special offshore instrument approach requiring two pilots, both of whom must be FAA approved to fly specific ARAs, are also generally a limited option because of these restrictions. Because of the restrictions and the fact that often the weather is the same over much of the Gulf, the alternate destination is most frequently land-based.

Twenty-seven IFR helicopter routes are available in the Gulf of Mexico. These routes were extended south to latitude 26° 30′ N in November 1990 to accommodate new oil exploration. Platform to platform IFR routes are desired by many users; however, the lack of low-altitude surveillance makes direct IFR routing between platforms unfeasible.

5.3.3.5 Enhanced IFR Infrastructure

Several of the largest companies expressed the desire for improved radar and communications coverage, and indicated that if better services existed, they would increase their number of operations and would fly more of those operations IFR (especially long-haul missions). Other companies said they would be happy to get low altitude radar coverage but that they considered it an additional safety feature rather than a means to increase their productivity. In general, most operators feel that additional radar and communications services would contribute to a safer flying atmosphere and are quite supportive of the idea of having the FAA provide flight following and low-level communications, rather than each company bearing the high expense of doing it for themselves, as is presently the case.

5.4 AIR TAXI/COMMERCIAL

The air taxi/commercial mission is found in every area of the United States and is operated under 14 CFR Part 135. The missions performed by air taxi/commercial helicopter operators include: photography, construction, powerline and pipeline patrol, geologic and seismic survey, executive transport, small package pick up and delivery, bank paper transport, sightseeing, and traffic reporting. Some of the larger Part 135 operators lease their helicopters to other operators in various parts of the United States for one specific purpose, such as offshore transportation, corporate/executive transport, or for EMS work. Some have contracts with government agencies which allow them to be called in cases of emergency for such work as fighting forest fires, floods, disaster relief, etc.

5.4.1 Mission Characteristics

Air taxi/commercial operators use all types of helicopters, from small piston helicopters like the Robinson R-22 to medium twin turbines like the Bell 222 and Sikorsky S-76. The most common types of helicopters used were found to be the Bell 206 (Jet Ranger), the Bell 206L (Long Ranger), and the Aerospatiale AS 350D (AStar), all of which are single-engine turbines.

Some operators own only 1 helicopter, while others were found to own as many as 85. The majority of helicopters are not IFR-equipped. Of those that are, most are not IFR-certificated for single pilot operation primarily due to the lack of an autopilot. The majority of pilots are IFR-rated but not necessarily IFR-current.

Of the different types of missions flown under the blanket heading of air taxi/commercial operations, photography and sightseeing were the most common missions.

No air taxi/commercial operator interviewed used more than one pilot to fly the aircraft. The usual number of passengers carried for each operation was two to four.

The number of annual operations for the Part 135 operators contacted ranged from 300 to over 7,000. The vast majority experience a business slump during the winter months, even in the southwest and in California which have milder climates. However, the winter slump is not necessarily dependent on how the climate restricts the aircraft's operation but can be mission related. For example, the sightseeing mission is dependent on the tourist season which in most areas comes in the warmer months. In some cases, the season does not create a slump, but individual days of bad weather may mean operations must be rescheduled. In other words, a photography shoot could be scheduled during the winter, but an individual flight might have to be canceled because of bad weather, if only for a day or two.

In some parts of the country, the seasonal decrease in operations may not come in the winter. For example, in the San Francisco/Oakland area, there are times of the year when fog presents a problem to helicopter flight. This is compounded by the fact that during the times when fog is most prevalent in the bay area, it is clear in the San Joaquin Valley, one of the primary destinations. Conversely, when it is clear in the bay area, it is often foggy in the San Joaquin Valley.

Of those who had IFR-certified helicopters, no more than 10 percent of their missions were flown IFR and most often as few as 1-2 percent. The most common reasons for not flying IFR were: IFR is not applicable to the mission; it is too expensive because a single-engine, single-pilot helicopter usually requires either an expensive autopilot or a copilot; flights take too long because they must conform to fixed-wing rules and infrastructure; there is not enough fuel capacity for the alternate destination requirement; the weight of the necessary equipment and/or fuel means a penalty in payload, either cargo or passenger load or both; and if the weather is bad enough to require IFR flight, then actual or forecast icing is likely to cause the flight to be canceled anyway.

5.4.2 Flight Characteristics

Although the operators interviewed are based in the counties identified in the location selection process, most of their flights take place within a 25 to 200 mile radius of their base of operation. Sometimes the base is located on the edge of a region that experiences very heavy air traffic, such as the

New York metropolitan area or the Washington, D.C./Baltimore areas. Often, due to the nature of the missions performed, these operators fly within the area of high air traffic activity and do little or no flying within the identified county.

The average en route altitude varies depending on where the operator is located, the size of the helicopter, the mission it is to perform, and how well equipped it is. In the north and central regions of the United States, helicopters tend to fly VFR between 1,000 to 1,500 feet AGL. In the Northeast in IFR conditions, helicopters follow the altitudes prescribed in the published IFR routes that were developed for fixed-wing aircraft between 6,000 and 10,000 feet AGL. In the western part of the United States, operators tend to fly at lower average en route altitudes. In California in particular, helicopters often fly VFR between 500-700 feet AGL, which is more likely to be in uncontrolled airspace. One important exception is in the Los Angeles Metropolitan area, where helicopters are asked to fly at 1,200 feet for noise abatement purposes.

When asked how they determined their most commonly flown routes, the majority of operators responded "direct" or "LORAN." When the response was "direct" and they were then asked if they used LORAN, they said they did. However, this response was most common in the eastern and central parts of the United States. Although most pilots fly VFR or SVFR by following landmarks, railroad tracks, rivers, roads, etc., those in California specifically said they navigated by following freeways. "Following freeways" was California's most common response, whereas in other parts of the country "LORAN" was the most common response. In fact, the San Francisco area has helicopter routes developed with air traffic control that use the freeways as the basis for navigation. Even if the freeway routes traverse control zones, as long as the controllers know the helicopters are following a freeway, their location is understood and accepted.

Some areas have published helicopter routes; some have letters of agreement with local ATC; and others have no specific helicopter routes at all. In most areas, the attitude of helicopter pilots that helicopters should be allowed to fly anywhere they want has declined. The advantages of specified routes and their benefits to both helicopter operators and ATC is now recognized. However, in many areas where there are no routes, the operators do not recognize routes as being of value.

Although the regulations specify the minimums for fixed-wing VFR operations as a 1,000 foot ceiling and 3 miles of visibility (1,000/3), helicopters can fly SVFR below those minimums with the only criterion being "clear of clouds." However, most operators have individual minimums, depending on pilot experience or company policy. Often there are different minimums for day, night, local, and cross country flights. The lowest minimums are for "day-local." "Night-cross country" flights have the highest minimums. The minimums used by the operators contacted ranged from clear of clouds to 1,000/3, depending on the time of day and the pilot's knowledge of the area.

When asked if there were other operational problems associated with the weather, operators in the New England/New York area most often cited icing as a problem. A number of flights in this area are performed IFR and frequently must be flown at altitudes at or above 6,000 feet AGL. Operators note that in the colder months it is common for temperatures at the surface to be slightly above freezing with visible moisture present. With a standard temperature lapse rate of 3.8 degrees fahrenheit per 1,000 feet, pilots are often required by ATC to fly through altitudes with temperatures in the freezing range and therefore are subject to icing. Unlike many fixed-wing aircraft, no rotorcraft are certificated to fly in icing conditions.

The Midwest has a similar climate as the Northeast but pilots did not cite icing as a problem primarily because they fly IFR less frequently. An operator in Michigan said that as long as the weather was good enough to drive, he would fly. Operators in areas other than the Northeast considered the regulation prohibiting operations in icing conditions to be so firmly established that they did not even think to comment on it until asked; then they would quote the restriction from the regulations.

In all parts of the country the attitude about thunderstorms was that isolated cells could be avoided, but storm fronts would inhibit any operations.

5.4.3 Operational Constraints

5.4.3.1 ATC Procedures

Most of the operational constraints described by those operators performing air taxi/commercial missions came from problems related to air traffic control procedures. The two most frequently heard complaints were that "the controllers treat us like fixed-wings," or that the "controllers need to be educated about the capabilities of the helicopter."

Ironically, it is in the areas where the most helicopter operations are conducted, the larger cities and terminal control areas (TCAs), that operators very often have the best overall rapport with ATC, yet these heavy air traffic regions can also create the most operational constraints.

In general, in areas with frequent helicopter operations, the controllers know who the local operators are; where they are going; and what they are doing. This is especially true for those operators who have been in the area the longest. These places also tend to have letters of agreement with air traffic control, indicating routes and procedures to expedite helicopter operations. Here, complaints stem from delays that occur only when the controllers are too busy to handle all the traffic efficiently. While air traffic control procedures state that aircraft will be handled on "a first come, first serve" basis, operators feel that helicopters usually have the lowest priority with controllers during the busy times.

The towers that were specifically mentioned by various operators as having delays during periods of heavy traffic were: Philadelphia, Boston, Washington National, New York LaGuardia, New York Kennedy, and Orange County, CA. Those

areas where basic procedures were considered a problem, i.e., having to contact too many tower personnel even for small changes in position, were San Jose, CA and Santa Ana, CA. Airports specifically mentioned by those interviewed, where it was difficult to get a SVFR clearance when the airport was IFR for fixed-wing traffic were Alameda Naval Air Station in northern California, and Burbank and Van Nuys in southern California.

Some of the larger airports like Los Angeles and Washington National do have discrete helicopter frequencies in the tower. However, the operators felt that some places like Washington National only used this frequency when they had been very busy for an hour or more.

In some locations, delays were reported when requesting permission to enter TCAs located outside the operators' normal operating area. Others had no complaints about the same TCAs. These operators felt that if the pilot was "professional," knew where he/she was and what he/she wanted to do, and communicated this to the controllers, then they were easily accommodated. This may mean just listening to the TCA ahead of time, finding out what is going on, and adjusting requests accordingly, or it may mean the pilot must call the tower by telephone before the flight, ask what the conditions are, and explain what he/she wants to do and where he/she wants to go. Philadelphia was one TCA specifically referenced as being difficult to transition. It was also considered more difficult to transition through the New York area than to land there.

Some helicopter operators have special arrangements with local ATC personnel. In Utah County, UT, helicopter operators have a discrete transponder code so that they can be readily identified by ATC. In more rural areas, such as Utah and western Maryland, the air taxi/commercial operators work almost exclusively in uncontrolled airspace, either due to the lack of controlled airspace or because of the nature of the mission, e.g., transporting geologists to remote areas or performing powerline and pipeline patrol.

Helicopter operators tend to have more problems with ATC outside of their immediate areas of operation, especially at the smaller towered airports. This is because controllers at these airports are less experienced with helicopters and their capabilities, and often try to put them into the fixed-wing pattern for landing or make them wait their turn in line with fixed-wing aircraft to take off using the runway.

Towers that were felt to have delays due to on-the-job training for controllers were Atlanta (Peachtree), GA, and Oakland, CA. However, since all ATC facilities are required to conduct this type of training, some inconvenience for pilots is probably unavoidable at one time or another.

Two towers specifically mentioned as being excellent at handling helicopters were Chicago O'Hare and Los Angeles International.

In the Baltimore/Washington, D.C. area, some operators said prohibited zones are more of a problem than TCAs or control zones. Similarly, some pilots mentioned that the prohibited zone at Camp Pendleton, the Marine Corp

training base in southern California, creates delays for pilots flying between San Diego and Los Angeles.

5.4.3.2 Radar Coverage

In almost all areas where air taxi/commercial missions operate, radar coverage was considered extensive and adequate for the operators' purposes. Few operators desired more radar coverage and then only for safety reasons so that they could be protected in areas where there is a high volume of fixed-wing traffic.

Pilots did report a few areas with "holes" in the radar coverage. One spot where the radar was not low enough to support helicopter operations near the American Legion Bridge along the Potomac River northwest of Washington, D.C.. Here, a helicopter must go up to 500 feet before it can be seen on Washington National Airport's radar. On the west coast, a hole was reported starting on the fringe of Oakland Airport and extending to the San Francisco Bay Bridge.

5.4.3.3 Communications Coverage

Air taxi/commercial operators were even more satisfied with the communications coverage available in their areas. No operator in any area stated the need for more communications services.

5.4.3.4 Current IFR Infrastructure

The vast majority of air taxi/commercial flights in every section of the United States are conducted VFR. The only area where helicopter operations are consistently flown IFR is in the Northeast Corridor between Boston and New York City, and within the New York Metropolitan area. The major constraints encountered are perceived by the operators to be predominantly due to ATC not taking advantage of the flight capabilities of helicopters, which is partially due to lack of understanding and partially due to the limits of the current system. Delays are also considered to be caused by excessive ATC workload.

Due to the exception for helicopters in the regulations which states that helicopters can fly SVFR if they stay "clear of clouds," and because of the helicopter's unique flight capabilities, many more helicopter operations can be performed SVFR than can be performed by fixed-wing aircraft. Consequently, the need for helicopters to fly IFR is often limited. For example, the ceiling minimum for an IFR nonprecision approach to the Indianapolis Downtown Heliport is 1,100 feet. With the SVFR rule tnat allows helicopters to fly clear of clouds, this makes flying IFR to this heliport unnecessary except in very poor weather. For the same reason, there is little demand at this time by the operators for helicopter IFR flight, except in areas of highly concentrated fixed-wing activity and high probabilities of IMC.

5.4.3.5 Enhanced IFR Infrastructure

If augmented CNS services were available, most operators said they would still not fly IFR much more than they currently do. Of the few who said they

would fly more often with IFR, the most common response was "slightly more often." They also did not believe that the types of missions flown would change or that the number of annual operations would significantly increase with increased CNS services. Those who now fly IFR said they would fly the same number of missions, but that the ratio of IFR to VFR flights would marginally increase. Of those who do not now fly IFR, few said they would fly IFR even if the current system was enhanced.

This lack of interest in an enhanced IFR infrastructure was mainly due to the operator's belief in a lack of IFR application to their mission. The air taxi/commercial operators found no need for IFR except when the helicopter was used strictly for transportation, small package delivery, or other such purposes where a strict schedule must be met. Most missions for which air taxi/commercial helicopters are used require at least a limited ability to see the ground from inside the aircraft, e.g., photography, powerline and pipeline patrol, sightseeing, construction, etc.

In fact, the few operators who said they would perform different missions if better helicopter IFR services were available, said the missions they would perform would be executive transport. Also, it was those operators who already performed a great deal of transportation and cargo services that said they might perform more operations if better IFR infrastructure was available.

5.5 SEARCH AND RESCUE

The air search and rescue mission is most prevalent in rural or unpopulated areas and at sea. The primary purpose of this mission is to locate persons who are lost or hurt on camping trips, hikes, skiing, boating, etc., and transport them to safety or to where they can get medical attention if needed. Search and rescue operations are most often performed by public agencies, such as police, fire, the U.S. Coast Guard, U.S. Park Police, etc. As public agencies they are given considerable latitude in following FAA regulations. Search and rescue helicopters are most commonly based at the agency's private heliport or at the agency's base at a local airport.

5.5 1 Mission Characteristics

Search and rescue operators use all types of helicopters, from small piston engine types to single-engine or twin-engine turbine helicopters, depending on their available funds. Small local police departments may use piston-engine helicopters, while larger Federal agencies may have twin-engine helicopters. The Coast Guard now uses only twin turbines. The types of helicopters used by those interviewed were the Schweizer/Hughes 300, Bell 47, Bell 206 (Jet Ranger), and the Bell 206L (Long Ranger). The Coast Guard uses Aerospatiale Dolphins.

The amount of agency funding also determines the number of helicopters operated. Local police may only be able to afford 1 piston helicopter, while the Coast Guard has about 150 twin turbine helicopters. No agency contacted, except the Coast Guard, had any IFR-equipped helicopters. However, many of the pilots were IFR-rated. An IFR rating is often required for safety in case they encounter inadvertent IMC.

Most search and rescue operators use only one pilot to fly the aircraft. Few passengers are carried, but additional "crew" are often flown on operations, most often to help in the search effort.

For those operators contacted, only one operator could estimate the percentage of SAR activity. This operator estimated that 2 percent of 1,200 flight hours were for SAR. The rest of the operators could only say that the percentage was small. Rotor and Wing International published a survey of public service operators in July of 1990. This survey reported that 3 percent of the public service operators do SAR as their main mission, and 17 percent do SAR as a secondary mission.

Most search and rescue operations are conducted in the summer, with spring and fall also active. This is due more to the fact that outdoor human activity corresponds to these seasons, rather than to any limitations caused by the climate.

No search and rescue operator contacted performed any operations IFR, except the Coast Guard. This was primarily due to the need to visually search, and secondarily due to the cost and weight of the equipment. Some search and rescue operators would like to be capable of flying IFR to areas where they are needed, despite the weather. The Coast Guard will fly IFR to the location of the rescue on the chance that the destination has VMC. If ceilings are low, they will try to stay below any clouds, if possible, and evaluate the chance of rescue. Most of these operations are conducted at sea in uncontrolled airspaces with minimal air traffic and few obstacles.

5.5.2 Flight Characteristics

Search and rescue operations have no set pattern of origins and destinations beyond their bases of operations. They must go where search activities are needed. Most of their operations are flown in uncontrolled airspace.

Average en route altitudes vary depending on the location. In rural areas the altitudes are lower than when traversing urban areas. Actual mission altitudes during search and rescue also vary but can be as low as 50 to 100 feet AGL.

Search and rescue routes are determined by the requirements of the mission. When the latitude and longitude of a search area are available, some agencies use LORAN to locate the area where they are needed.

Because public agency operators are not obligated to strictly adhere to the FAA regulations, they sometimes fly in extremely poor weather conditions if the pilot feels that he/she can successfully do so.

5.5.3 Operational Constraints

5.5.3.1 ATC Procedures

The search and rescue mission has few if any problems with the ATC system. Police, fire departments, and Federal agencies are given priority when on a search and rescue mission.

5.5.3.2 Radar Coverage

Search and rescue operators did not cite the lack of radar coverage as a problem. While they often fly in remote areas below radar coverage, flights are performed VFR in areas outside of terminal airspace with minimal traffic. They therefore have few needs for radar service.

5.5.3.3 Communications Coverage

There were no problems with communications cited by search and rescue operators. Most police and Federal agencies have better radio communications equipment than other aircraft. This extra equipment is needed to keep abreast of aircraft information and to communicate with their agencies during flight.

5.5.3.4 Current IFR Infrastructure

Since no search and rescue operator flies IFR except the Coast Guard, and because ATC gives them priority during emergency flights, these operators had no problems with the current IFR infrastructure. Coast Guard search and rescue missions are performed mainly at sea and are therefore flown outside of controlled airspace.

5.5.3.5 Enhanced IFR Infrastructure

Those search and rescue operators contacted who would like to fly IFR would do so when conducting other than search and rescue missions. Local and state police departments are often called on to perform duties other than search and rescue, such as transporting dignitaries and government officials. They felt that in performing an actual search or rescue mission, though, CNS improvements would not be helpful.

5.6 BUSINESS

The business mission is found in every area of the United States. These missions are flown as an alternative to ground transportation by the owner of the business who most often also owns the helicopter. This mission is most commonly operated under 14 CFR Part 91. The helicopter used for the business mission can be based at a local airport or at a private heliport located at the business headquarters or, in some cases, at the owner's home. The operator usually flies from the base to branch offices, to the airport to connect with commercial flights, and to other areas such as mines or manufacturing plants associated with the main business of the company.

5.6 1 Mission Characteristics

The helicopters most commonly flown in the business mission are single-engine piston and single-engine turbines. Common types of helicopters used are Robinson R-22s, Enstroms, Schweizer/Hughes 300's, Bell 206 (Jet Rangers), Bell 206L (Long Rangers), and Aerospatiale AS 350D (AStars) and AS 355 (Twin Stars). The majority of helicopters are not IFR-equipped, and the pilots are usually not IFR-rated.

No business operator used more than one pilot to fly the aircraft. The number of passengers carried for each operation can range from one to four, depending on the type of aircraft.

The number of annual operations for all business operators contacted ranged from 100 to 600 operations per year. Business missions are usually planned on a year round schedule, unless the business supported by the helicopter is itself seasonal. Individual days of bad weather in any season have a more limiting effect on operations than do seasonal variations.

The value of IFR operation to the company is decided by the owner. Of the operators contacted, those who did fly IFR flew less than one percent of their operations IFR. The operators who did not fly IFR gave their reasons for not doing so as inapplicability to the purpose of the business; cost; and penalty in payload of either cargo or passenger space, or both, due to the amount and weight of the fuel required for the alternate destination and the weight of the equipment itself. Another reason business operators did not fly IFR is the lack of nonprecision approaches at heliports.

5.6.2 Flight Characteristics

Business operators usually have specific origins and destinations, defined by business demands, to which they fly repeatedly over consistent routes. Their operational area is often relatively close to their home base, when compared to other missions. However, sometimes medium or long distance cross-country trips are made by business operators.

The average en route altitudes vary depending on where the operator is located, the size of the helicopter, and how well equipped it is. In the northeast helicopters tend to fly at higher altitudes, normally between 1,000 to 2,000 feet AGL. In the western part of the country operators tend to fly at lower average en route altitudes. In California the usual altitude is between 500-700 feet AGL, which is often uncontrolled airspace. One important exception is in the Los Angeles area, where helicopters are requested to fly at 1,200 feet for noise abatement purposes.

The majority of the routes that business operators fly have been determined by the most direct route between origin and destination, usually by LORAN. Published helicopter routes and letters of agreement are other ways that routes are determined.

Minimums for VFR operation are usually set by the person who owns the helicopter, according to his/her own experience. For business operators these

ranged from 600/2 in familiar areas to 1,000/3 in unfamiliar territory. Business operators are limited by icing, but they are less likely to encounter icing than missions that regularly fly IFR at higher altitudes, because the majority of business operations are flown VFR or SVFR at lower altitudes.

5.6.3 Operational Constraints

5.6.3.1 ATC Procedures

Business operators believed ATC procedures were a constraint. One business operator complained that he was delayed by ATC as often as 50 to 75 times a year, and that these delays were often as long as 15 to 30 minutes. The biggest problem that these operators have is receiving a clearance to fly SVFR out of their base during IMC and into areas of known VMC where they conduct their business. Complaints were also expressed that helicopters are treated like fixed-wing aircraft and that controllers need more education about the capabilities of helicopters.

These operators have fewer problems with ATC in areas where they most often fly. Those who frequently fly the same routes in the same area do become known to local ATC personnel and are more easily accommodated. However, heavy traffic at peak hours often causes delays. More problems are encountered at airports where helicopters are infrequent visitors, because controllers have a tendency to treat them like fixed-wing aircraft.

5.6.3.2 Radar Coverage

Few business operators reported any problems with radar coverage. The New England region was one exception. Problems were reported west of Boston where radar coverage was considered poor at 2,000 feet. Additional radar was said to be needed on the westerly VFR arrival route to Logan International in Boston South and west of Hanscom Field near Bedford, MA at and below 2,000 feet the radar was reported "spotty." One operator said the controllers complained that they can see aircraft from the tower before they can see it on radar. There were reported problems in western Massachusetts and north to near Jaffery, NH. Radar was also considered weak north of a line from Laconia, NH to Pease AFB on the New Hampshire coast.

5.6.3.3 Communications Coverage

Overall, the business operators were satisfied with the communications coverage available in their areas. The only place that reported a need for better communications was on the westerly VFR arrival route to Logan International in Boston, MA.

5.6.3.4 Current IFR Infrastructure

Business operators tend to fly very few IFR flights due to their low experience/currency levels and lack of mission requirements for IFR flight. These operators therefore did not express any complaints with the IFR infrastructure.

5.6.3.5 Enhanced IFR Infrastructure

When discussing the possible use of IFR if augmented CNS services were available, most operators still felt they would not fly IFR. Since business operators tend to use heliports to enhance the time saving direct route capability of the helicopter, they felt that they would want to fly IFR only if there were some way to get IFR approaches to and departures from heliports. Otherwise, they did not see the need for it.

5.7 CORPORATE/EXECUTIVE

The corporate/executive mission is found in most large cities and metropolitan areas, but the heaviest concentration is in the Northeast. This mission provides helicopter transportation for executives or employees of large businesses or corporations. The distinction between this mission and the business mission is that for corporate/executive, a pilot is hired expressly to fly the helicopter; it is not flown by the owner of the helicopter. Some corporate/executive missions operate under 14 CFR Part 135 and some under Part 91. Corporate/executive missions can be based at a local airport or at a private heliport. They usually fly business executives, employees, or clients to the company's regional offices, to manufacturing plants, mines, etc. Other uses of the helicopter are to exhibit the company's product, like real estate developments, and to fly personnel to airports to connect with commercial flights. Sometimes they fly the chief executive officer between work and home.

5.7 1 Mission Characteristics

Corporate/executive operators use either single-engine turbine or twin-engine turbine helicopters. There is a higher concentration of large, twin-turbine helicopters used for this purpose in the Northeast. In the West, particularly the Southwest and California, there are very few twin-engine helicopters operating. One exception is in the Los Angeles area where there are comparatively more twin-engine helicopters than in other western locations. Twin-engine turbine helicopters are more likely to be used by the major corporations. The most common types of helicopters used were found to be the Bell 206 (Jet Ranger), the Bell 206L (Long Ranger), the Aerospatiale AS 350D (AStar) or AS 355 (Twin Star), the Bell 222, and the Sikorsky S-76.

While most companies only own one helicopter, others may own five or more. Of those operators interviewed, the slight majority of their helicopters were IFR-equipped and certificated, and most of the pilots were IFR-rated and current.

Most corporate/executive operators hire only one pilot per aircraft. Those with the larger, twin-turbine aircraft, specifically the Sikorsky S-76, use two pilots to satisfy IFR requirements. The average number of passengers carried for each flight is three.

For those operators contacted, the number of annual operations for the corporate/executive mission ranged from 1,100 to 1,500. The most active time for most of the operators was spring to fall. Some operate all year and

others have only a certain time of the year that is active due to the type of business the company conducts. Individual days of bad weather do limit some operations in all seasons.

Icing tends to be more of a problem in the Northeast Corridor, because the pilots fly the published IFR routes that were developed for fixed-wing aircraft and must fly at altitudes (6,000-10,000 feet) where icing is more likely. Therefore, even when IFR operation is normally possible, flights are often canceled due to actual or forecast icing.

Of those contacted who fly IFR, the percent of time they fly IFR ranges from 2 to 30 percent. These operators were all located in the Northeast. None of the corporate/executive operators contacted outside the Northeast said they flew IFR.

The most common reasons given for not flying IFR were: SVFR allows more flexibility in operation; the cost of the equipment or extra personnel needed makes IFR operation uneconomical; there is loss of payload due to the weight of the equipment needed and/or weight and quantity of fuel needed for the alternate destination requirement; IFR approaches to heliports are lacking; and there are too many delays in the current IFR system for helicopters.

5.7.2 Flight Characteristics

Due to the nature of the mission, most corporate/executive operations have more or less the same origins and destinations over the same routes. Corporate/executive missions fly to private and public heliports more than other missions, because their main purpose is to save time for the company's executives or employees as compared to alternate modes of ground transportation. Since most company headquarters are located in urban and suburban locations, corporate/executive flights are more likely to fly in and around major metropolitan areas and into major airports. Helicopters are therefore more likely to operate in controlled airspace.

Average en route altitudes vary depending on the part of the country where the aircraft operates, the size of the helicopter, and the kind of avionics it carries. The larger the helicopter and the better equipped it is, the higher the altitude. Helicopters in the Northeast tend to fly at higher altitudes. For VFR, corporate/executive operations in the Northeast average 1,400 feet AGL, although one operator stated his company flew "below 6,000" VFR and another reported 2,500 feet AGL for VFR flight. For IFR operations one operator said he flew at 10,000 feet AGL and another at 6,000 to 8,000 AGL. In the Midwest, operators said they flew around 1,200 feet VFR, and in California, the operators tend to fly VFR between 500 and 1,000 feet AGL. However, in the Los Angeles area all helicopters are requested to fly at 1,200 feet AGL for noise abatement purposes.

When asked how they determined their most commonly flown routes, there were three common answers. The first two were "direct" or "LORAN." The third was published helicopter route charts where these are available. Often the only established routes are approach and departure paths to the airport that have been determined through letters of agreement between the operators and

ATC. Other responses were "pilotage" and "experience." In California, following the freeways was the most commonly stated procedure.

Individual operators often set their own or company minimums, depending on their own experience. The minimums for corporate/executive range from 300 feet and 1 mile to 1,500 feet and 3 miles, depending on how well the territory is known and the time of day.

Icing was the most common weather constraint mentioned in the New England/New York area. This is because these operators fly published IFR routes at altitudes of 6,000 to 10,000 feet where icing is more likely. Icing may force cancellation of a flight that would normally have no other problem. Those operators who fly primarily VFR or SVFR usually fly at lower altitudes and are therefore less likely to encounter icing, even in the colder climates.

The general attitude about thunderstorms was that isolated cells could be avoided but that storm fronts would inhibit any operations.

5.7.3 Operational Constraints

5.7.3.1 ATC Procedures

Corporate/executive operators believe the ATC system constrains their operations. Although ATC personnel are very familiar with helicopters in areas where most helicopter operations are conducted, general congestion of airspace and peak hour operation often create delays for helicopters. Many operators feel helicopters become the lowest priority aircraft during these times.

Corporate/executive operators reported that one of the problems associated with delays caused by excessive ATC workload was receiving a clearance to go through a TCA. This is especially frustrating because in the time it takes to receive their clearance they can fly around the TCA. Five to 10 minute delays are experienced routinely at New York LaGuardia and New York Kennedy Airports, 15 minute delays at the Islip, NY, airport radar surveillance area (ARSA), and maximum delays of 30 minutes are encountered en route to South Hampton. This is especially pronounced during IMC when there are extensive delays due to departing fixed-wing traffic at these airports. Helicopters are forced to fit into the fixed-wing infrastructure, usually behind fixed-wing traffic that is landing or departing. Mornings tend to be less of a problem than do afternoons. Other operators had no problems in the same areas, although most said LaGuardia was a problem during peak traffic.

In addition, due to the flight capability of helicopters, the operators do not feel that they should have to go through the basic procedure of having to talk to clearance delivery, then ground, then the tower only to move a few feet, and then wait for a slot in which to take off. They feel this causes unnecessary delays and does not take advantage of the helicopter's capabilities.

Helicopter operators in the Boston area had encountered very few problems until recently when the FAA conducted a review of their operating certificate

and CFR 135.183, Performance Requirements: Land aircraft operated over water which states in part:

> "No person may operate a land aircraft carrying passengers over water unless -...
>
> (b) It is necessary for takeoff or landing;...
>
> (d) It is a helicopter equipped with helicopter flotation devices."

Approaches and departures to and from the Logan helipad involve flying over a portion of the Inner Harbor. For several years helicopter operations had been permitted under the provisions of paragraph (b), but this review placed the emphasis on paragraph (d). This new interpretation imposed a weight penalty that effectively removed one passenger seat and reduced the operator's profit margin, severely impacting their ability to operate economically.

For helicopter operations between Teterboro and Essex County, NJ there are reported delays of 10 to 20 minutes during IFR conditions.

In the St. Louis, MO area, pilots solve their problems with the TCA by avoiding it altogether. They said that within the TCA they are treated like fixed-wing aircraft and are given the lowest priority, especially at Lambert Field. It was suggested that VFR corridors in this area would be helpful.

5.7.3.2 Radar Coverage

Overall, corporate/executive operators had no complaints about the radar coverage, but a few problem spots were mentioned.

In the Morristown, NJ area there is no surveillance coverage below 1,800 feet MSL. Between New York and Boston, pilots reported a few locations with surveillance gaps below 3,000 feet MSL. However, the minimum en route altitude (MEAs) of the Victor airway between the two cities is at or below 2,500 feet and pilots did believe this altitude provided surveillance coverage.

In Boston, there are some problems with radar because of the tall buildings. The Prudential and John Hancock Insurance Company buildings were specifically identified as blocks to radar coverage. There is also a hole below 3,000 feet westbound towards Hartford, CT, where for 20 miles there is no coverage. Some operators use the radar at the headquarters of United Technology/Sikorsky to get them through this area.

5.7.3.3 Communications Coverage

Corporate/executive operators were well satisfied with the communications coverage available in their areas. No operator stated the need for more communications services in any area.

5.7.3.4 Current IFR Infrastructure

Although the majority of corporate/executive flights are conducted VFR or SVFR in every section of the United States, there is a great deal of helicopter IFR activity in the Northeast Corridor between Boston and New York and the adjoining metropolitan areas. It is believed by the corporate/executive operators that major ATC constraints are encountered due to a lack of understanding on the part of controllers of the flight capabilities of helicopters.

Due to the exception for helicopters in the regulations that states that helicopters can fly SVFR if they stay "clear of clouds," and because of the helicopter's unique flight capabilities, helicopter operations can be performed SVFR in conditions that force fixed-wing aircraft to fly IFR. The operators believe that at this time, the need for helicopters to fly IFR is limited.

5.7.3.5 Enhanced IFR Infrastructure

When discussing possible increased use of IFR if augmented CNS services were available, most operators still felt they would not fly IFR very often. The most common response was "slightly more often." Even in the heavy traffic environment of the northeastern United States, few operators were interested in increased IFR services for helicopters. This includes those operators who fly IFR regularly and have experienced problems in the current system. Those who do not now fly IFR feel that it is not economical due to the expense of equipment and the penalty in payload involved.

One reason specifically stated by the corporate/executive operators for this lack of interest in an enhanced IFR infrastructure was that there are no IFR approaches to heliports where these operators most often go.

5.8 SCHEDULED COMMUTER

Scheduled commuters currently operate in the Boston, New York, and Los Angeles metropolitan areas. They provide a quick and reliable means of transportation in and around these areas. The use of scheduled commuters is expected to continue as metropolitan areas become more congested. However, one of the two operators in Boston recently suspended scheduled commuter operations temporarily.

5.8.1 Mission Characteristics

Although scheduled commuters in Boston, New York City, and Los Angeles perform the same mission, their operations differ. Operators in the Boston area primarily operate Bell products, with variations of the Bell 206 representing eight of the nine helicopters employed by the two operators. Of the nine aircraft, only one is IFR-equipped and the remaining aircraft operate exclusively under VFR or SVFR. Scheduled commuters in the Boston area typically carry one crew member and from four to six passengers. A fully equipped Bell 222, which operates IFR approximately 10 percent of the time,

carries one crew member and up to eight passengers. Load factors for the Boston operators typically run about 75 percent.

New York operators employ larger helicopters capable of higher passenger loads than the Boston scheduled commuters. These operators use Sikorsky helicopters for the most part. Among these are three Sikorsky S-61N's and four S-58T helicopters. The S-61N's carry 2 crew and up to 24 passengers and the S-58T's carry 2 crew and up to 14 passengers. Load factors in the New York area run about 65 percent. Operations in the New York metropolitan area are conducted under VFR or SVFR. Scheduled service between the Manhattan heliports and LaGuardia Airport was recently suspended. However, these operations were in effect at the time the telephone interviews were conducted, and the operator hopes to resume them at a later date. Therefore, the information concerning operations to/from LaGuardia has been included.

The Los Angeles operator uses four Aerospatiale AS-350's (AStar) for that commuter service. The aircraft are operated with one crew member and typically from three to six passengers. The load factor for these operations runs approximately 70 percent, with a marked seasonal variation. The summer months support approximately twice as many passengers as the winter months. None of the four aircraft are IFR equipped; therefore, all flights are flown under VFR or SVFR conditions.

5.8.2 Flight Characteristics

Scheduled commuter operations in the New York area are flown primarily between heliports located in Manhattan, LaGuardia Airport, and Kennedy International Airport. Regular service has also been available between Manhattan and the Atlantic City pier area. Operations occurring between Manhattan and the New York airports are short in duration and are flown below 1,500 feet AGL. Flights between Manhattan and Atlantic City last approximately 50 minutes and are typically flown at 3,000 feet AGL.

All flights occurring in the New York area are flown by visual reference on pre-established routes and are conducted under VFR or SVFR conditions. Most operations between Manhattan and Atlantic City are flown under VFR; however, during IMC these flights will be flown under IFR. No helicopters currently in scheduled commuter use are certified for flight into icing conditions.

Although there are a large number of scheduled commuter operations at Logan International Airport, operations in the Boston area occur throughout much of the local area and encompass more operating sites than those in the New York area. Flight lengths are typically short in duration (less than 15 minutes) and are almost exclusively flown by visual reference under VFR or SVFR conditions. One helicopter is used for IFR operations; however, these flights operate to destinations outside the Boston area, such as New York or New Jersey. Flights within the Boston area are conducted below 2,000 feet AGL on routes that have been pre-established with local ATC facilities.

Operations in the Los Angeles area are flown principally along two routes. One route runs between Los Angeles International Airport and Santa Ana Airport

with an intermediate stop at a heliport in San Pedro. The second route is between San Pedro and Santa Catalina island. Flights are of short duration and are flown between 500 and 1,500 feet AGL on existing helicopter routes. All flights are flown by visual reference under VFR or SVFR conditions.

5.8.3 Operational Constraints

5.8.3.1 ATC Procedures

Delays at New York LaGuardia were mentioned by several operators and were attributed to two factors. First, the large number of helicopter operations in and around the metropolitan area causes delays. Another cause for delays is the number of communication frequency changes and ATC contacts that are required. Prior to takeoff, the normal routine is to first contact clearance delivery, followed by succeeding contacts with the ground controller, the local controller, and finally the departure controller. During peak traffic periods, the time required for each communication contact increases, which increases the total delay time.

There were no significant delay problems reported for operations occurring to and from Kennedy International Airport. These scheduled commuter operations occur between the 34th Street Heliport on the east side of Manhattan and Kennedy Airport.

In general, scheduled commuter operators in the New York area were quite satisfied with handling by air traffic controllers. However, they did recommend a dedicated controller for helicopter operations in the New York area. As a minimum, the operators felt that a dedicated controller during peak traffic periods would be extremely beneficial to their operations, especially at LaGuardia Airport. The need to contact ATC could possibly be limited to contacting the ground controller to taxi and the dedicated helicopter controller for landing and departing the airport, thereby reducing delay time.

Scheduled commuter operators in Boston reported delays in and out of Logan Airport due to procedure changes. Helicopter operations into and out of Logan Airport were altered near the end of 1989 as ATC procedures were changed. As a result, operators reported that 5 to 10 minute delays for flights into or out of Logan were common during peak traffic periods when Runway 27 was in use for departures. One operator reported that during these times, their operation would experience over an hour of delay time by the end of the day. Suggestions for possible alternate routings into and out of Logan during these periods are being discussed between the operators and ATC.

Boston does employ a separate controller during peak traffic periods to control helicopter traffic. This practice expedites rotorcraft operations in and around Logan Airport. During non-peak periods, one controller works both the tower and helicopter frequencies. Rotorcraft may call this controller on either frequency. This, however, creates a bit of confusion for other helicopter pilots operating in the area, in that they can only hear the controller's side of the conversation if the other aircraft is on a different

frequency. Operators have suggested that all airborne rotorcraft communications should be limited to a single frequency.

A Los Angeles operator reported that he experienced very few delays throughout the year and that any ATC delays were only for 1 or 2 minutes. These delays occurred when flying to Los Angeles International Airport. When traffic is heavy at Los Angeles Airport, rotorcraft may be asked to hold for a brief period until ATC can work them into the flow of traffic. These brief delays do not present any significant problems to the operator.

5.8.3.2 Radar Coverage

In general, the scheduled commuter operators in both the Boston and New York areas reported only minor gaps in radar coverage. These areas occurred at low altitudes and did not present a problem to the operators. Reported gaps in radar coverage occurred primarily because of tall structures within the metropolitan areas. The Los Angeles operator was not aware of any surveillance gaps in his operating area.

5.8.3.3 Communications Coverage

Scheduled commuter operations in the New York area occur between Manhattan, LaGuardia Airport, and Kennedy International Airport. Due to the tall buildings located in Manhattan, communications with LaGuardia Airport from the west side of Manhattan below approximately 700 feet are extremely limited. In general, though, operators in the New York area reported only minor gaps in communications coverage.

Operators in the Boston area also reported minor gaps in Logan International's communications coverage west and south of the downtown area (see section 7.2). Once again, these gaps are created by the metropolitan skyline.

5.8.3.4 Current IFR Infrastructure

Some delays are experienced operating in Atlantic City during IMC conditions. When proceeding to the Atlantic City area during IMC, the normal procedure is to fly an instrument approach to Atlantic City airport and then to proceed SVFR through the Bader Municipal Airport control zone to the pier area. Delays occur when trying to transit through the Bader airport nonradar control zone. If another aircraft is in the control zone, the helicopter must hold outside until the control zone is clear. Delays of up to 20 minutes have been reported. Figures 5 and 6 illustrate the problem of operating in a nonradar control zone. Without positive radar identification, the controller cannot allow the helicopter to transit the control zone until other aircraft are clear of the control zone. Two alternatives to alleviate these delays include additional radar coverage to provide positive low-level radar separation, or design and implementation of a LORAN-C nonprecision approach to the pier area, thereby bypassing the need for the approach to the Atlantic City Airport and the transition through the Bader control zone.

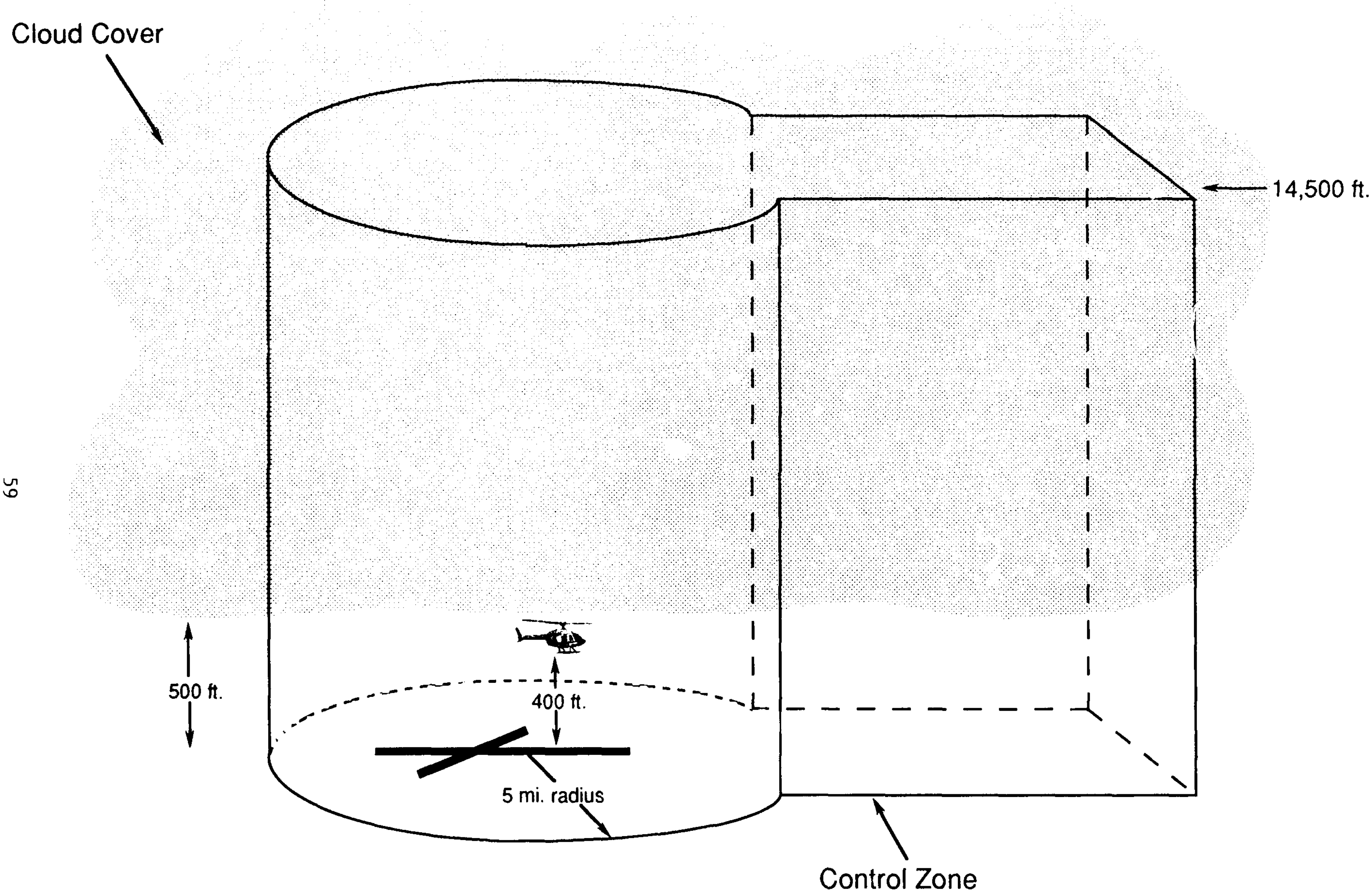


FIGURE 5 ROTORCRAFT TRANSIT THROUGH CONTROL ZONE

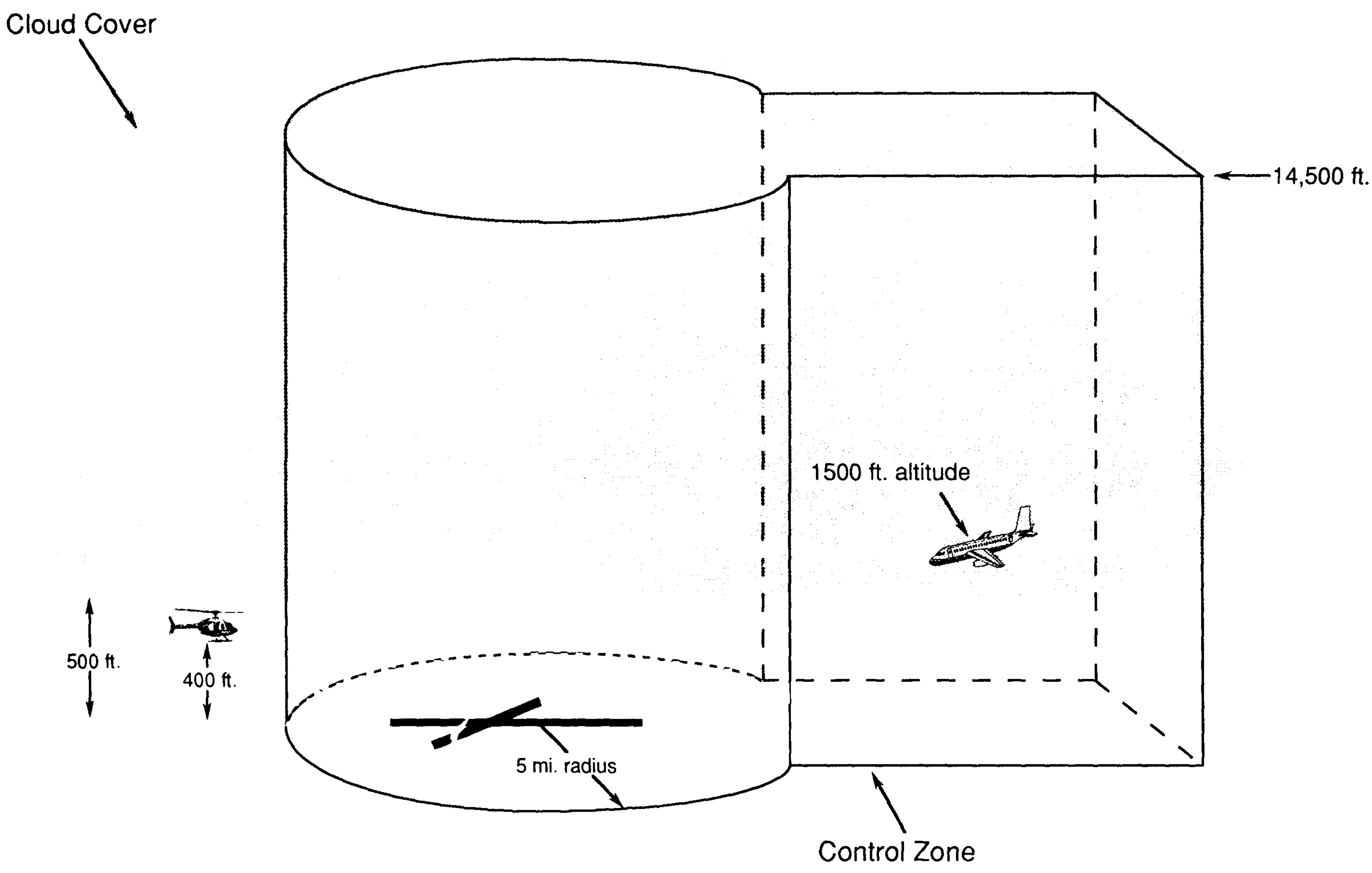


FIGURE 6 ROTORCRAFT "HOLD" IN NONRADAR ENVIRONMENT

5.8.3.5 Enhanced IFR Infrastructure

All of the operators interviewed said that the minor radar and communications gaps that exist in their areas do not currently hamper their operations. In general, they felt that coverage was quite adequate and that additional radar or communications sites were not necessary.

5.9 SUMMARY OF OPERATIONAL REQUIREMENTS

Discussions with helicopter operators, regardless of the mission, led to a number of recurring comments. These comments address VFR operations and IFR operations, CNS shortcomings, and air traffic procedural difficulties.

The vast majority of helicopter operations are conducted VFR. Many Part 91 and Part 135 operators have typical day local minimums as low as 500 feet and 1 mile while night local and day non-local minimums are typically as low as 800 feet and 2 miles. These minimums permit safe operations and yet are low enough not to warrant the need for an IFR certificated helicopter or IFR current pilots. In general, operators' VFR minimums are similar to the nonprecision approach minimums in their operating areas.

Pilots also commented that the primary obstacle to purchasing an IFR-certificated helicopter and maintaining IFR-current pilots is cost. An IFR capability requires helicopters to either have an autopilot or a second pilot and an enhanced stability augmentation system. In a highly competitive helicopter service industry, these additional costs, which are passed on to the customer, may prevent an operator from being profitable. Air traffic delays that are incurred while awaiting IFR access to the National Airspace System add to these costs, as do the reduced capacities that result from the additional weight associated with the necessary IFR avionics and/or second pilot.

Additional operational requirements also hamper IFR operations. The availability of an alternate destination with adequate weather is often a problem with aircraft that fly as slowly as 130 knots. The requirement to fly to the destination and still have 30 minutes of fuel aboard (FAR 135.223) adversely affects payload size. In addition, for Part 135 operators, stringent restrictions are placed on single-engine helicopters that effectively limit operations in IFR conditions to 15 minutes from the departure airport (FAR 135.181 (c)(2)(i)).

<u>Despite these detractions, the trend towards IFR capable rotorcraft continues</u>. This trend is the direct result of a decrease in both avionics cost and weight relative to airframe costs and weights. This trend should continue well into the future as advances in avionics further decrease component size, cost, and weight. However, strict IFR operational restrictions placed on single-engine Part 135 flights by 14 CFR 135.181 (Performance requirements: Aircraft operated over-the-top or in IFR conditions) are not expected to change. For this reason, IFR operations performed for hire will continue to be performed primarily by twin-engine helicopters.

Current IFR operators consider the lack of low altitude CNS to be minimal and not a major problem. Locations that are exceptions are the Gulf of Mexico, a few sparsely populated areas, and a few specific sites where buildings blocked line of sight coverage.

Operators did identify procedural and/or controlling problems. The primary focus was that they were not fixed-wing aircraft. They believe if they could be separated from fixed-wing traffic, especially in the terminal areas, both fixed-wing and rotary-wing aircraft would incur fewer delays. Specific improvements to procedures and services which would alleviate these problems are identified in section 6.3.

5.10 FUTURE TRENDS

The results of the operator interviews indicate that the majority of helicopter operators have few problems that could be alleviated by increased IFR operations. That may, in fact, be true for the present. The operators interviewed indicated that the vast majority of their current operations are conducted in a VFR/SVFR environment which is very flexible and accommodates their current needs. However, there are indications that things may change in the near future. In particular, the availability of nonprecision approaches and worsening airport/airspace congestion problems will be factors which will favor the trend toward increased use of IFR by rotorcraft.

The factors which currently discourage IFR operations by rotorcraft operators have been discussed, by mission type, earlier in this section. They universally include: lack of precision and nonprecision approaches, 14 CFR Part 135.22 which specifies alternate airport and fuel requirements for IFR flights, and SVFR minimums as low as, or lower than, IFR minimums. The impact of all three of these factors will be changing over the next 10 to 15 years in such a way as to favor increased IFR operations. By 1992, advances in the integrity and availability of the LORAN navigation signal may allow the development of low-cost nonprecision approaches in most locations in the United States. This will also provide a wider choice of alternate airports which will relieve some of the problems operators currently have with 14 CFR Part 135.22. In addition, as airport and terminal airspace congestion worsen, SVFR clearances will likely become much more difficult to obtain, forcing helicopter operators to fly IFR, abort their mission, or find other landing sites outside the control zones. These factors can potentially lead to a substantial increase in rotorcraft IFR operations. Furthermore, as automated weather stations come on-line in the 1990's, providing more timely and detailed weather information for a broader range of airports, the alternate airport requirement will become less of a discouragement to IFR operations as alternate airports where the weather is above minimums will be more readily available.

The purpose of this section is to postulate what effects the predicted increased use of rotorcraft, especially in the IFR environment, will have in the next 10 to 15 years in terms of expected trends in airspace management and airport congestion. An overview of several different predictions of future trends in rotorcraft activity was presented in section 6.0 of the first report (reference 10).

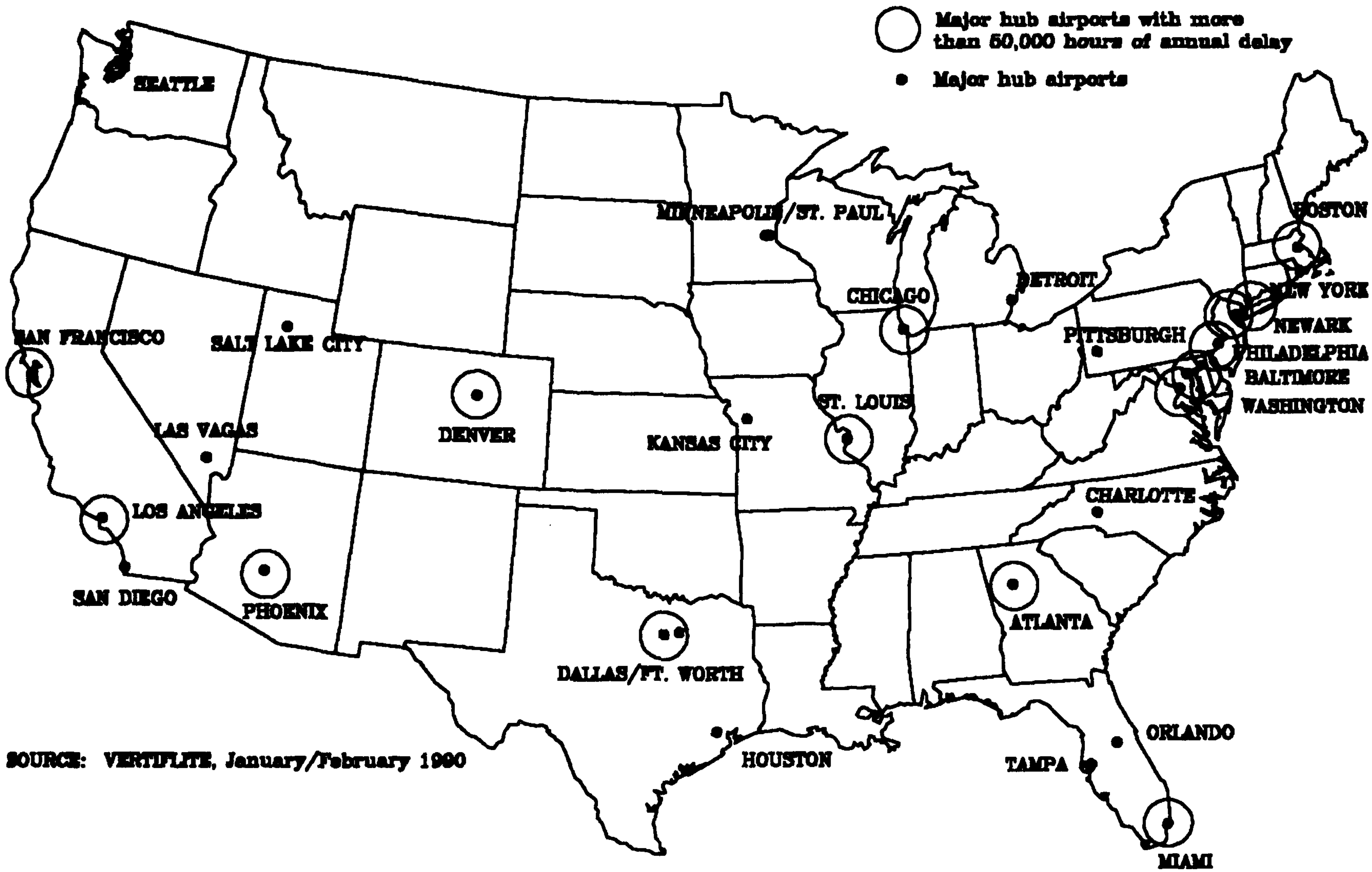
5.10.1 Airport Congestion

Perhaps the most pertinent aspect of the future operational environment for all aircraft will be the continued, worsening congestion at hub airports. This will be particularly relevant to helicopters, since their approach speeds, approximately 90 knots, are slower than the approach speeds of large fixed-wing aircraft used by air carriers (160 knots slowing to 125 knots). Because of this speed differential, the two aircraft types do not mix well in a congested IFR environment. Helicopters currently pose an airspace management problem to controllers in a mixed aircraft, IFR environment. Without changes to terminal airspace management it is probable that this problem will become worse in the next 10 to 15 years. (The terminal airspace management problem is discussed in detail in section 8.0.)

The hub and spoke system adopted by the major air carriers since deregulation of their business in 1978 has led to serious congestion, which in turn has led to delays of greater than 20,000 air carrier hours at each of 21 airports today (reference 21). Furthermore, the number of seriously congested airports is expected to double by 1997. This delay cost the airlines and passengers approximately $5.1 billion in 1986 (reference 26). This is more than twice the cost of airline delay in 1976 in constant 1986 dollars. Figure 7 depicts the hub airports which will each have more than 50,000 hours of air carrier delay by 1997. Note the concentration of congested airports in the Northeast Corridor. Major hub airports in six of the sites in the Northeast Corridor selected for further analysis in this study are each predicted to have more than 50,000 hours of air carrier delay by 1997. In addition, seven of the other sites selected for further study in this report are predicted to be congested by 1997. In all, 13 of the 15 sites predicted to have greater than 50,000 hours of air carrier delay by 1997 were selected for detailed analysis in this study. Thus, it appears that airport congestion is going to be a significant factor affecting future rotorcraft operating conditions.

As major hub airport congestion continues to escalate, it is expected that policies affecting aircraft operations at these airports will be developed and implemented in the next 10 years. This will probably entail some sort of landing fee, such as the one recently attempted at Boston Logan Airport, which will be expensive enough to discourage general aviation's use of the congested hubs. Unless capacity enhancements for rotorcraft can be developed and approved, these new pricing policies would likely apply to rotorcraft. This would have a detrimental effect on rotorcraft growth. It would discourage IFR flight into congested hub airports and restrict the growth of commuter, air taxi, and corporate/executive rotorcraft operations at important destinations. It is not expected to impact the growth rates of EMS or offshore operations.

On the other hand, it is also anticipated that the air carriers will try to enhance the utilization of hub airports by using larger aircraft which will be able to carry more passengers per operation. This will have the effect of overloading the landside facilities of many hub airports, creating an imbalance with the airside capacity of those airports. Indeed, many of the access roads and other public transport facilities serving the airports are



SOURCE: VERTIFLITE, January/February 1990

FIGURE 7 AIRPORTS PREDICTED TO HAVE MORE THAN 50,000 HOURS OF AIR CARRIER DELAY BY 1997

already overcrowded. The use of rotorcraft to transport passengers to and from these crowded airports could alleviate some of the projected landside congestion. One estimate is that a rotorcraft-based transport system could handle as much as 10 percent of the landside passenger traffic at busy hub airports.

Another possibility, especially in the Northeast Corridor, is for rotorcraft to be used to transport passengers directly from city center to city center. This would require a network of heliports to support a large number of rotorcraft operations. This is a distinct growth possibility for commuter and corporate/executive operators. However, there are many improvements which would have to be made to the aviation infrastructure before such a network of vertiports/heliports could be viable. In particular, communications down to the surface, instrument approaches, control zones, and additional ATC procedures to support IFR operations would be necessary to provide the level of schedule reliability necessary for such a commuter operation to be viable.

5.10.2 Airspace Congestion

Another problem facing rotorcraft operators in the near future is an increase in terminal area airspace congestion. According to the March 1990 FAA Aviation Forecasts, there were 45.0 million IFR operations in 1989. This number is expected to increase to 59.6 million IFR operations in 2001, an annual increase of 2.7 percent. The mix of instrument operations is also expected to become more heterogeneous over the forecast period. The number of commuter/air taxi and general aviation operations performed by smaller aircraft is expected to increase at a substantially faster rate than the number of operations performed by the larger air carrier aircraft (46.4 percent versus 32.8 percent). By 1999, 62.0 percent of all instrument operations are expected to be performed by commuter/air taxi and general aviation aircraft, up from 58.0 percent in 1987. Rotorcraft are part of this expected increase in IFR operations. In fact, there are indications that rotorcraft IFR operations may be increasing faster than IFR operations for other types of aircraft.

Telephone interviews with major helicopter manufacturers and after-market avionics finishers indicate that the percentage of IFR-equipped helicopters being manufactured is increasing rapidly. Bell Helicopter Textron indicated that approximately 50 percent of their new civil helicopters delivered are IFR-equipped. Sikorsky Aircraft indicated that 100 percent of their new civil helicopters delivered are IFR-equipped. Interviews with after-market finishers and with Helicopter Association International (HAI) personnel indicated that almost all heavy/medium twins and intermediate twin helicopters are IFR-equipped; many of them are IFR-certified. Approximately 50 percent of the light twins and 25 percent of the light single helicopters are IFR-equipped. However, most piston engined helicopters are not IFR-equipped.

A distinction between IFR-certified and IFR-equipped helicopters is necessary, since IFR-equipped only indicates that the aircraft has some form of nonprecision approach guidance onboard, such as a localizer. IFR-

certified, on the other hand, indicates that the aircraft has been approved by the FAA for flight into IMC.

There are several other indicators which reveal a trend toward future increases in IFR rotorcraft operations. A recent survey of EMS operators in Hospital Aviation indicated that over 61 percent of the helicopters used for EMS are twin-engine turbines, and the other 39 percent are single-engine turbines. The percentage of twin turbines has been steadily increasing for the last 5 years. Thus, EMS operators have been acquiring more capable aircraft every year. The telephone interviews with EMS operators also indicated that a high percentage of the helicopters are IFR-equipped (92.9 percent), and a high percentage of the pilots are IFR-rated and current (nearly 100 percent). In fact, many large EMS operators require that their pilots be IFR-rated and current. These two facts indicate that there is an identified need for IFR operating capability, even if the operators do not currently feel that it is cost effective. It is probable that EMS operators will expand their IFR operations in the future based on this identified availability of IFR aircraft and pilots.

A recent survey of corporate helicopter operators in Rotor & Wing magazine indicated that 85 percent of corporate helicopter pilots are IFR-rated and 50 percent of the helicopters are IFR-certified. In addition, the survey found that 9 percent of the corporate flight hours were IFR in 1989. Therefore, it is probable that corporate/executive and air taxi operators will also expand their IFR operations in the future based on this identified availability of IFR aircraft and pilots.

Another indicator that the percentage of helicopters and helicopter operations conducted under IFR is increasing is found in figures 8 and 9. Using data taken from the FAA General Aviation Activity and Avionics Survey (GAAS) for the years 1982 through 1988, it was found that registered turbine helicopters have declined at an annual rate of 0.48 percent and that turbine helicopter flight hours flown have increased at a 1.09 percent annual rate over those years. However, the number of helicopters flown in IMC has increased at a 1.8 percent annual rate, and the number of IMC flight hours has increased at a 7.0 percent annual rate over the same period. While the figures recorded in the GAAAS are difficult to compare to other surveys and predictions because of the sampling methods used (see section 6.0 of the first interim report (reference 10) for a discussion of the GAAAS sampling methods), the two figures compare data collected using the same sampling methodology. Therefore, the differences in the rates of increase are considered significant, in that they indicate that the use of turbine helicopters for IFR flight is increasing faster than the use of turbine helicopters overall.

The percentage of helicopters being sold that are IFR certificated continues to increase. Also, many operators are retrofitting their helicopters to acquire IFR capabilities. It can be concluded that while many operators stated they rarely or never fly IFR, the trend is to be IFR-capable and conduct more IFR flights.

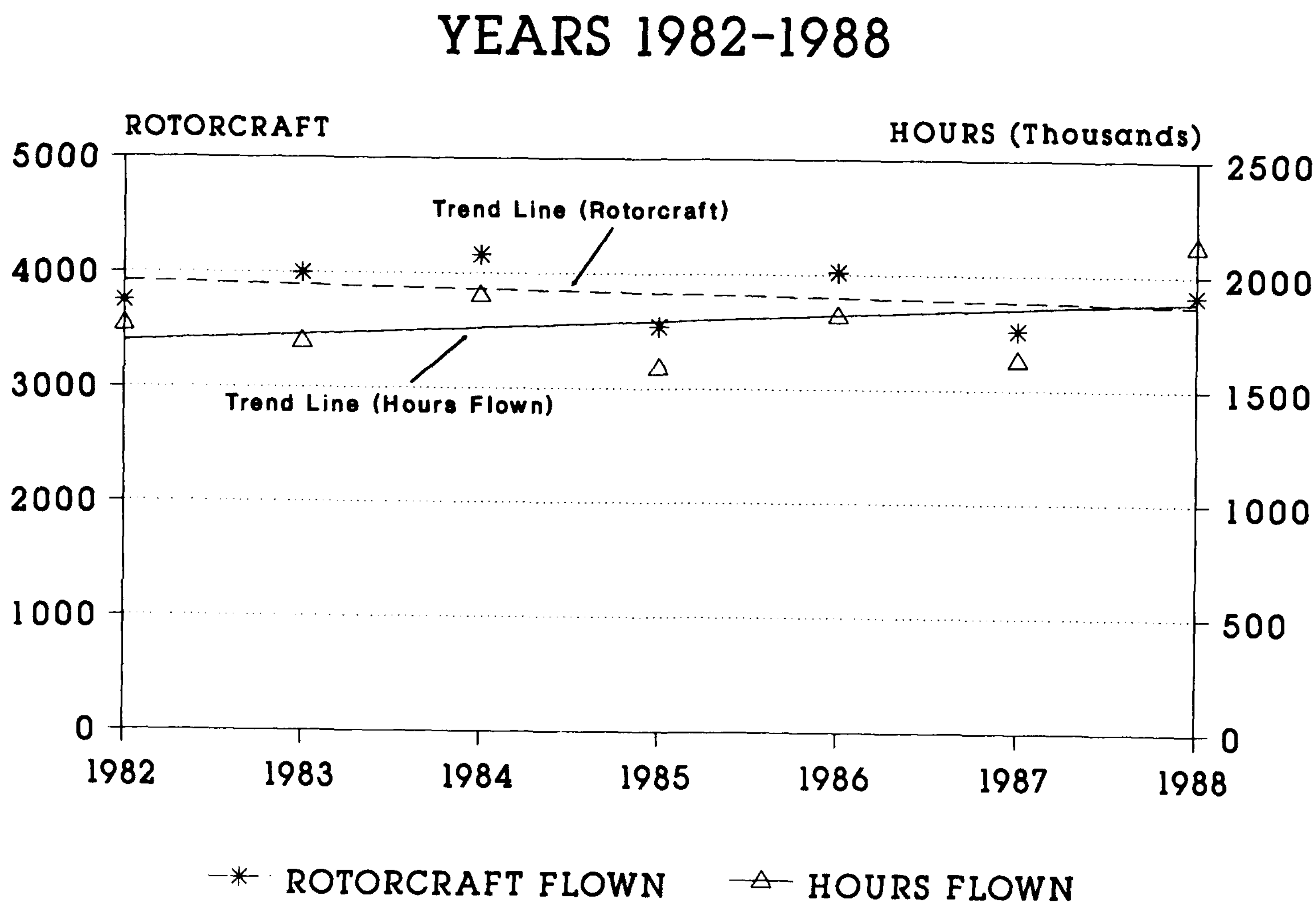


FIGURE 8 TURBINE ROTORCRAFT FLOWN

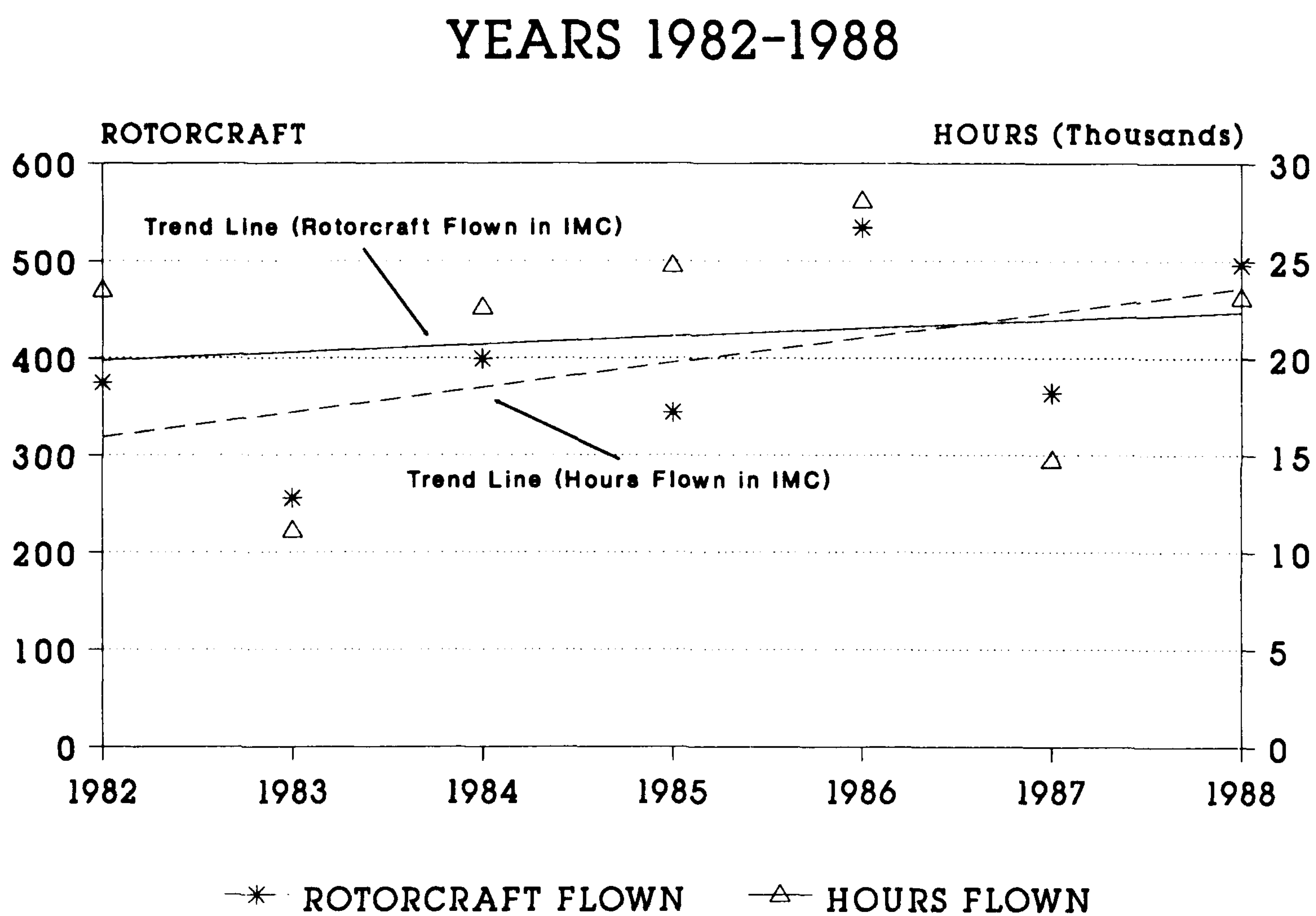


FIGURE 9 TURBINE ROTORCRAFT FLOWN IN IMC

6.0 ENHANCEMENTS TO FUTURE ROTORCRAFT OPERATIONS

CNS equipment, rotorcraft avionics and ATC policies and procedures will continue to evolve as new technologies are developed. Understanding the most likely advancements and establishing a timetable for their implementation is an essential step to assessing NAS shortcomings as they relate to rotorcraft operational needs. This understanding is difficult because it must, by necessity, predict an uncertain future. The assessment is however, based on the 1990 Aviation System Capital Investment Plan (CIP) (reference 54), the Rotorcraft Master Plan (reference 11), the Research, Engineering, and Development (R,E&D) Plan (reference 12), the FAA Level 1 Design Document (reference 7), and other documented technical assessments of the future.

6.1 FAA CAPITAL INVESTMENT PLANS

The 1990 edition of the CIP outlines a methodical modernization of the National Airspace System and identifies new projects that could add significant new capabilities. The FAA vision of user community needs, technical innovation, and ongoing modernization programs as contained in the CIP, provide the foundation of this study's assessment of the future. A number of additional programs not included in the CIP also appear possible and are therefore included. For the purposes of this project, all modernization programs included in the CIP, except for those contained in the new capabilities chapter (chapter 6), will be assumed to be completed on schedule and all costs to be sunk. The proposed projects included in the new capabilities chapter are considered to have significantly different technologies than today's systems. Also, implementation of these projects is less than certain. The usefulness of appropriate chapter 6 projects for rotorcraft are therefore considered in this project. These modernization programs will be considered, where appropriate, for meeting additional rotorcraft community needs.

6.1.1 NAS Communications Projects

Current NAS communications projects include the following: upgrading tube-type equipment with solid state components, consolidation of facilities to reduce maintenance and cost, and implementation of Mode Select (Mode S).

6.1.1.1 VHF/UHF Communications

ATC communications make use of frequencies located in the very high frequency (VHF) band for civil aircraft operations and ultrahigh frequency (UHF) for military use. VHF propagation is predictable and reliable; however, the drawback is that these frequencies are limited by line-of-sight constraints. Therefore, the signal is blocked by mountains and man-made obstacles. In addition, the signal is limited in range at low altitudes because of the curvature of the earth. For the most part, VHF coverage throughout CONUS is adequate for rotorcraft use; however, problems arise in mountainous regions, urban areas, and in the Gulf of Mexico.

The NAS Plan objective is to guarantee voice communications coverage down to 2,000 feet AGL except in areas where there is little air traffic. This

objective will not satisfy the needs of those rotorcraft operators who operate at low levels in remote areas, rough terrain, urban centers, or offshore.

Existing VHF communications service could be improved by adding more remote communications air/ground (RCAG) facilities in areas where helicopter activity is high. Remote sites could be connected to the nearest ATC center using leased phone lines, or dedicated satellite links. The number of sites needed depends on the degree of coverage improvement desired. Even with an increase in the number of stations, there will still be areas where coverage to ground level is not possible, primarily in mountainous and urban areas.

Satellites could provide a near ideal system by providing reliable coverage to ground level, even in mountainous terrains and urban centers. Currently, there are no projects in the NAS plan involving the use of satellites to provide communications coverage. However, ICAO, the Radio Technical Commission for Aeronautics (RTCA), and the FAA are evaluating designs employing satellites, along with ground-based systems, to support future communications services.

The FAA's research, engineering, and development work is also on-going in the area of satellite communications. A detailed assessment of technical and economic characteristics, risk factors, transition strategies, and availability is scheduled to be completed in 1995.

The need to develop satellite communications for domestic use as a supplementary communications system or in some locations as a primary system is unclear. The planned terrestrial based communications infrastructure appears adequate to meet fixed-wing aircraft operational needs in most areas and will remain the preferred network in high-density terminal areas. However, to achieve communications coverages in remote areas and at low-altitudes in the year 2010, (the year this study will use for satellite communications availability) some satellite-based communications appears necessary.

6.1.1.2 Mode S

The Mode S program will principally provide enhanced surveillance; however, it will also offer users a digital data link capability. This data link will enable automated information exchange between the pilot and the controller, without tying up overburdened VHF communication channels. The data link will allow the user to access ATC instructions and weather data, including remote sited automatic weather station information. Figure 10 provides an implementation timeline for several NAS subsystems. Mode S with data link capability is scheduled to be fully operational by FY 2000.

6.1.2 NAS Navigation Projects

Current NAS projects include several navigation system developments and improvement programs. These include VHF omnidirectional range/distance measuring equipment (VOR/DME), LORAN, NAVSTAR global positioning system (GPS), and microwave landing system (MLS) programs. The VORTAC, LORAN, and GPS

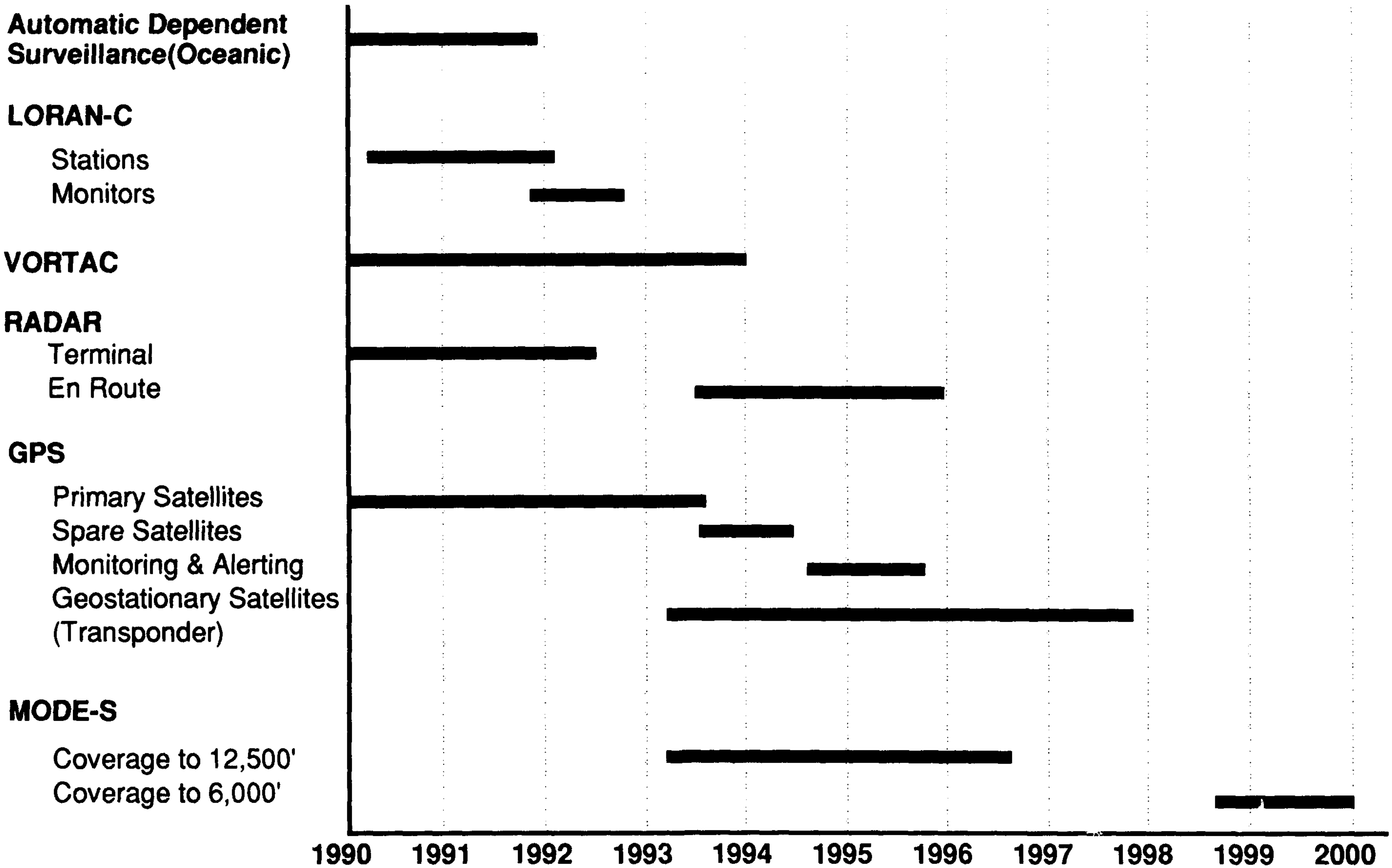


FIGURE 10 NAS SUBSYSTEM EVOLUTION

systems provide both en route and terminal area navigation capabilities. However, MLS is specifically a terminal area approach, landing, and departure system. When considering applications for rotorcraft operations throughout the United States, MLS is fully capable of supporting rotorcraft operations in the terminal area. However, as one of the ground rules of this study, precision landing capability is considered to be beyond the scope of the current effort. Therefore, MLS will not be discussed further in this CNS benefit-cost context.

6.1.2.1 VOR/DME

The NAS VOR/DME program includes projects which are designed to upgrade and improve the current VHF omnidirectional range/distance measuring equipment (VOR/DME) system, collocate DME with VOR stations, and relocate stations to sites that will provide better coverage for the airway structure. The project includes the addition of remote maintenance monitoring for efficiency and cost reduction. The upgrades to the system and the remote maintenance monitoring capability have been achieved. Relocations are managed at the FAA regional level. In general terms, the VOR/DME network is well established and only a few relocations and new establishments are anticipated.

Currently, there are nearly 1,000 VOR/DME stations located throughout the United States. This system provides accurate and highly reliable coverage. However, the system is limited by line-of-sight constraints. Therefore, as in VHF communications, terrain features, the curvature of the earth, and man-made obstacles limit the useable range of the system. These limitations are critical to rotorcraft operations because they typically operate at lower altitudes. Given these inherent line-of-sight constraints in the VOR/DME system, it is economically impractical to establish enough sites for this system to provide blanket coverage at typical rotorcraft operational altitudes over the entire United States. As a consequence, the rotorcraft community has increasingly equipped their aircraft with LORAN which can be received at rotorcraft operational altitudes.

6.1.2.2 LORAN-C

LORAN-C is a ground-based low frequency radio navigation system which provides area navigation information that is independent of line-of-sight constraints. Although it was established by the U.S. Coast Guard as a marine navigation system, LORAN-C currently provides coverage suitable for aviation navigation over most of the eastern and western United States. Additional station installations will fill the current mid-continent coverage gap, thereby providing coverage throughout all of the CONUS and also improving coverage in the Gulf of Mexico. The southern two-thirds of Alaska also has LORAN-C coverage. Position accuracy for the system is approximately 0.25 nautical miles. The NAS LORAN-C program includes installation of signal monitors. These monitors will collect signal information in order to provide data concerning system accuracy and to forecast seasonal variations. This information will provide data to support the development of LORAN-C nonprecision approach procedures.

Several LORAN-C nonprecision approaches currently exist having been approved on a "limited implementation" basis. However, the system as currently configured lacks a means of automatically alerting pilots when the system is out of tolerance. Therefore, to be suitable for nonprecision approaches, the signal must continually be monitored by ground personnel to alert pilots when the system is out of tolerance. A new LORAN-C capability to automatically alert pilots when the system is out of tolerance, called "aviation blink," is expected to be operational in 1992. This system will alert pilots within 10 seconds (an FAA requirement) when the signal exceeds tolerance limits. Currently, the system must be out of tolerance for more than 60 seconds before users are alerted. This time period is adequate for marine users but will not support nonprecision approaches. "Aviation blink" will enable the FAA to approve LORAN-C nonprecision approaches over approximately 90 percent of the United States once the system is fully operational. Interagency agreements between the FAA and the Coast Guard must be finalized and funding approved before this feature becomes operational.

LORAN-C's ability to provide area coverage independent of line-of-sight, to the surface, and at a reasonable cost to the user makes the system extremely valuable for rotorcraft purposes. The expected ability to provide nonprecision approaches throughout the CONUS and much of Alaska once "aviation blink" is fully functional will also be of great benefit to rotorcraft operators.

6.1.2.3 GPS

GPS, being implemented by the Department of Defense (DOD), is a space-based radionavigation system which is expected to provide worldwide navigation coverage. GPS will employ a constellation of 21 primary satellites and 3 spares. Users will obtain a three-dimensional position fix (latitude, longitude, and altitude) by using signals from four or more satellites. System accuracy for civil users is projected to be 100 meters horizontally and 156 meters vertically. This accuracy will provide the capability to establish GPS nonprecision approaches.

Since GPS is space-based, it will provide coverage to the surface. This will provide near ideal navigation capability to rotorcraft missions, especially in mountainous regions and urban locations. One of the drawbacks to GPS is that if one or more of the satellites becomes inoperative, "holes" in the coverage may occur.

Another issue with GPS that has yet to be fully satisfied is the manner in which integrity monitoring will be achieved. Integrity monitoring alerts pilots when navigation information has degraded beyond the required tolerance. This is an extremely important issue, especially in light of the fact that GPS will be expected to support nonprecision approaches. One current plan is to have ground integrity monitors uplink messages to transponders onboard geostationary satellites, which will in turn broadcast these integrity messages to aircraft. Another concept considers the use of GPS combined with other systems to allow the receiver itself to ascertain signal integrity. Another concept employs the use of geostationary satellites to provide independent navigation information to aircraft as an alternate source of

position information for pilots. However, the final policy on civil aviation use of GPS has yet to be decided. The entire GPS system, including integrity monitoring and pilot alerting, is expected to be certified and operational about 1998.

6.1.3 NAS Surveillance Projects

Several NAS surveillance projects are being developed to support more accurate surveillance capabilities and also to provide surveillance where none currently exists. Surveillance projects include upgrading both terminal and en route radars; and implementation of Mode S, automatic dependent surveillance (ADS), and LOFF.

6.1.3.1 Radar Improvements

Both terminal and en route radars will be replaced or upgraded as a result of current NAS projects. These changes will replace tube type equipment with solid state components and introduce remote maintenance monitoring which will significantly reduce maintenance costs. Radar is limited to line-of-sight applications. Therefore, inherent limitations with this mode of operation, such as blockage of the signal by terrain or man-made obstacles and curvature of the earth, will continue to limit the range of radars. A lack of radar coverage at low altitudes will continue to exist in many areas.

6.1.3.2 Mode S

A new method of providing accurate and reliable secondary radar surveillance data, known as Mode S, is expected to be fully operational by FY 2000. This technique, which is compatible with existing air traffic control radar beacon system (ATCRBS) transponders, is also designed to provide data link services to equipped aircraft. The overall plan is to provide improved services and, through radar networking studies and relocations, to provide Mode S surveillance coverage down to 6,000 feet mean sea level (MSL) or to the minimum en route altitude along designated routes, whichever is higher.

The Mode S project will improve the surveillance capability over that of the ATCRBS. Mode S provides more accurate position information and minimizes interference. This is accomplished by discrete interrogation of each aircraft and improved processing of aircraft replies. In addition, Mode S provides the medium for a digital data link which will be used to exchange information between aircraft and various ATC functions and weather data bases. These weather data will enhance flight safety and user productivity by providing current information for flight operation.

Required Mode S systems will be procured in stages. The first stage will provide coverage down to the ground at 108 terminals and down to 12,500 feet MSL in other areas (complete in 1996). The second stage will provide an additional 60 systems and will extend the coverage down to 6,000 feet MSL or minimum en route altitude (MEA), whichever is higher (complete in 2000).

Mode S will meet rotorcraft operational requirements in areas where the coverage extends down to typical rotorcraft operational altitudes. However,

due to line-of-sight limitations, it is impractical to consider Mode S for widespread coverage across the United States at all rotorcraft operational altitudes.

6.1.3.3 Automatic Dependent Surveillance (ADS)

ADS is an all-weather system designed to provide controllers with aircraft position information for purposes of providing separation in areas which lack radar coverage. ADS makes use of onboard derived navigation data to supply position information to controllers. This navigation data will be provided through en route facilities via a communications link; for oceanic routes, data may be relayed by employing satellites.

The current NAS ADS project will be used to separate aircraft over oceanic routes. Information will be provided to both the New York and Oakland Centers for separation over Atlantic and Pacific routes. ADS is expected to allow less restrictive separation criteria and an increased number of operations.

6.1.3.4 LORAN Flight Following (LOFF)

Another ADS system the FAA has evaluated is LORAN offshore flight following (LOFF). This system could provide IFR surveillance and reduce IFR separation in portions of the Gulf of Mexico where helicopters are supporting offshore oil and gas wells. The FAA recognizes the need for surveillance in the Gulf of Mexico and LOFF as one possible solution. Because of this, LOFF has been included in the new capabilities chapter of the CIP. This chapter addresses new ATC requirements that utilize systems that are different from existing or planned ATC equipment.

LOFF would relay airborne LORAN derived latitude and longitude to air traffic controllers. Position information would therefore be available to controllers for equipped IFR helicopters everywhere that LORAN-C and an information relay capability are both available. Based on the FAA's investigation into LOFF, air traffic controllers believe "that system operational performance was nearly indistinguishable from that of radar. Differences in radar vs LOFF position were judged to be small enough that the presence of two targets for a single aircraft would not pose a problem. Also, the system was judged to be sufficiently reliable and accurate to enable handoffs to be made to or accepted from adjacent radar sectors" (reference 52).

IFR separation standards using LOFF have not been ascertained but is thought that 10 nautical miles should be adequate based on our discussions with air traffic controllers involved with the project. This separation standard would more than double the current IFR airspace capacity. The other advantage of LOFF is it would cost considerably less than primary radar to cover the same area.

Several issues must be resolved before LOFF becomes integrated into the NAS. First, LOFF must be fully certified before it is used for IFR separation. Since LOFF is a sole-means surveillance system, erroneous position information would effect both the navigation and the surveillance

system. Also a back-up navigation system would likely be required for system reliability and integrity before LOFF would be certified. Non-directional beacons (NDB's) are now available and could conceivably be the back-up system. Another possibility is GPS. Second, a method of "time-sharing" transmissions from aircraft must be devised. Currently, aircraft transmissions "step over" or block each other when simultaneous transmissions occur. Finally, discrete frequencies in an appropriate portion of the radio spectrum must be allocated for use by LOFF. Provided that these technical and operational challenges can be met, LOFF could provide a solution to the current lack of FAA surveillance coverage in the Gulf of Mexico.

Currently, there are several tracking systems ("Flite-Track" and "Inflite Tracking") not operated by the FAA that are being successfully used for flight following by the helicopter operators in areas where radar coverage is inadequate or nonexistent. This is especially true today for helicopters engaged in offshore oil and gas support in the Gulf of Mexico. These flight following systems, which are owned by independent companies, are similar in concept to the FAA's LOFF Program. An aircraft automatically relays its position (latitude/longitude) to a base station computer. Tracks can be updated at 5 second intervals, but since most helicopters fly at relatively slow speeds, the displays are typically updated only once each minute in order to observe movement. If no update is received within 3 minutes, the system alarms and action is taken to contact the pilot to verify his flight status. A few blind spots do exist in the system and tracks are occasionally dropped as a result. However, the base station verifies each track drop to assure safety.

LORAN-C will be available at most U.S. locations once additional stations become operational. Therefore, in concept, an ADS system based on LORAN-C information could be used for surveillance purposes in remote areas throughout the United States. Such a system has the potential to provide nearly 100 percent surveillance coverage in locations where there is communications coverage. Another navigation system that could potentially be used for ADS purposes is GPS. Like LORAN-C, GPS will provide near-blanket navigation coverage down to the surface over the entire United States. The potential exists to use GPS or LORAN-C separately or in combination for both navigation and surveillance information.

ADS systems use navigation information and communications links as a substitute for radar surveillance systems. The navigation aspect of ADS is being adequately addressed by LORAN-C and, in the future, GPS. The communications link can be addressed through technologies such as VHF/microwave land links and/or satellite communications. These issues will be addressed in greater detail in the final report for this rotorcraft low altitude IFR benefits/cost study.

6.1.4 NAS Plan Enhancements Summary

The following observations briefly summarize the analysis of ATC system enhancements provided for in the CIP:

1) the CIP does not specifically address rotorcraft requirements; rotorcraft are only considered as an element of the overall NAS requirements;

2) line-of-sight systems, i.e., VHF communications, VOR/DME, radar, Mode S, can be used to meet rotorcraft requirements at specific locations that are relatively small in size (approximately 25 miles radius at 400 feet altitude, 55 mile radius at 2,000 feet altitude); and

3) widespread CNS services at low altitudes are probably best met by non-line-of-sight limited systems, i.e., LORAN-C, GPS, communications satellites, and automatic dependent surveillance.

6.2 ENHANCED AVIONICS

Research and development efforts are leading to engineering advances that may increase the civil rotorcraft operator's ability to operate safely at night and in all-weather situations. Advances in cockpit visual aids, sometimes termed "visionics," will allow the pilot to "see" outside the aircraft using light intensification and/or synthetic vision systems. This section will discuss the technical aspects of a number of visionic systems. These systems include:

- head's-up displays (HUD),
- night vision goggles (NVG),
- wire detection systems,
- low light level television (LLLTV),
- forward looking infrared (FLIR) systems, and
- millimeter-wave (MMW) radar.

While a few of these systems are commercially available, technical advances are constantly increasing their capability and performance.

Improvements in visionics have the potential of increasing the capability and flexibility of civil helicopter operators. Operators involved in specific functions, such as EMS, SAR, offshore oil and gas, fire fighting, law enforcement, and air taxi, may benefit the most from advances in visionics. However, because of the cost of these systems, they are not likely to be practical for the low budget operators. Some estimates for future military programs are that avionics and related systems (e.g. visionics) will comprise 50 percent or more of new rotorcraft acquisition costs. Admittedly, the military requires state-of-the-art equipment; however, these estimates do highlight the fact that not all technological advancements are likely to be economically practical in the civil market. The following sections discuss some of the technical aspects of current and future visual aids.

6.2.1 *Head's-Up Displays*

Head's-up displays (HUD) make use of nearly transparent screens, called "combiners", to present critical flight information to the pilot. These combiners are located between the pilot and the windscreen. The virtue of the HUD is that the pilot sees this information without having to look down, as is

the case with normal cockpit displays known as head-down displays (HDD). With HUD, therefore, pilots can view critical flight information and the outside world simultaneously. Information such as altitude, airspeed, heading, and attitude are expressed in symbols and alphanumeric characters called symbology. Navigation and precision approach guidance information are also displayed on HUD.

HUD symbology is focused at infinity. This allows the pilot to look through, and not at, the combiner to see the information. As a result, the pilot does not have to refocus his eyes each time he wants to look at HUD information. Two types of displays are available: holographic and non-holographic. Holographic displays tend to offer a wider field of view (FOV) than non-holographic displays. Also, holographic combiners have a higher transmissivity than non-holographic displays. Non-holographic displays tend to make the outside world appear dimmer than it actually is.

HUD allows the pilot to navigate using instruments and to look outside the aircraft at the same time. This is extremely valuable during instrument approaches, particularly during times of very low ceilings and/or visibility. In fact, HUD displays have proven to be so reliable that the FAA has certified manual CAT IIIa approaches for certain aircraft using HUD, whereas CAT IIIa approaches without HUD require full autoland capability.

Currently, HUD is not certified for use on rotary-wing aircraft. However, this visual aid could become an integral part of the cockpit for various operators as the demand for all-weather capabilities increases.

6.2.2 Night Vision Goggles

Night vision goggles (NVG) are electro-optical devices that allow the pilot to see a near day-like presentation at night. They operate on the principle of light amplification. Reflected light entering the NVG is electronically amplified thousands of times, and the enhanced image is then displayed to the pilot. Currently, the third generation of NVGs, commonly referred to as Gen III, is in use. Gen III goggles are extremely light sensitive and are fully operational on overcast starlit nights, whereas the earlier models (Gen II) required at least 23 percent moonlight at an angle no less than 30 degrees above the horizon.

Gen III NVG's consist of two image intensifiers, one in each of two monocular units. The two monocular lens units are typically attached to a helmet and are positioned approximately 1 inch in front of the pilot's eyes. Pilots are able to look around and under the NVGs to view cockpit instrumentation. Gen III NVGs have a field of view of approximately 45 degrees. Their spectral response is highest in the red and near-infrared (IR) regions of the light spectrum. This makes Gen III NVG's very useful in starlight, since starlight has a high proportion of near-IR radiation.

One drawback of NVG's is that strong sources of visible light can cause an effect known as "blooming." Blooming occurs when the NVGs are saturated by light. This effect tends to wash out that area of the image where the light source is located. Gen III NVG's are able to compensate somewhat for this

blooming effect through automatic gain control circuitry. However, this compensation does degrade other portions of the display. NVG's do recover very quickly once the light source is removed.

Since NVG's are sensitive to light sources, internal cockpit lighting is an important consideration. The goggles are typically fitted with a "blue-minus" filter. This filter removes the blue-green portion of the light spectrum. Therefore, NVG-compatible military cockpits typically employ blue-green filters for internal lighting, instrumentation, and warning/caution/advisory lights. FAA testing is underway to determine if such cockpit changes are required if (when) NVG's are approved for use in civil helicopters. Existing cockpits may be retrofitted to accommodate NVG use if the need should arise. However, this capability could represent a one-time additional cost burden to the operator.

Two other factors must be considered when using NVG's. The first is the ability to see small obstructions. In general, because of their size and the minimal amount of light that they tend to reflect, wires are not easily seen with NVG's. The second factor is that NVG's are not an all-weather system. Fog or heavy precipitation hinder their functional use. However, despite these factors, NVG's remain a possible way to extend helicopter operations into the nighttime, thereby increasing the usefulness and cost-effectiveness of rotorcraft.

6.2.3 Obstacle Detection Systems

Flying at low levels is inherently more dangerous than flying at higher altitudes for several reasons. In particular, the pilot needs to avoid obstacles, such as wires, transmission towers, and antennas, which pose extreme danger to low-level flying. This is especially true for nighttime missions. Wires continue to be the most commonly struck obstacle, day or night. In fact, transmission line lightning strike protection cables, which are the top cables used for transmission lines, are the most common wires struck by helicopters. A system that is able to detect these and other hazards could significantly reduce the likelihood of obstruction strikes.

The FAA is currently supporting efforts to examine obstruction avoidance capabilities. This effort involves several aspects, including operational procedures, obstruction marking/lighting techniques, obstruction detection systems, and obstruction protection systems. The overall objective of the project is to design techniques and systems which might be used by rotorcraft operators to avoid or successfully negotiate obstructions.

Currently, commercial wire detection systems are available. However, they are limited in that they only detect energized wires. These units can detect large transmission wires up to one mile away. Smaller, local lines may be detected as much as a third of a mile ahead of the aircraft. These units provide both an audio and visual warning to the pilot and are NVG compatible.

The U.S. Army has undertaken an aggressive program to develop a sensor system to detect trees, antennas, wires, transmission towers, and other obstacles that their pilots may encounter during low-level missions. Under

the Obstacle Avoidance System (OASYS) program, the Army envisions a helmet-mounted display which would be capable of warning the pilot of an obstruction. This display is expected to be compatible with NVG's and forward-looking-infrared (FLIR) systems.

The OASYS program is designed to evaluate four separate methods of obstruction detection. The first method involves the use of an active system called millimeter-wave (MMW) radar (see section 6.2.5.2). The OASYS MMW radar uses a 3.2 mm wavelength beam which corresponds to a frequency of 94 GHz to detect obstructions. This wavelength gives MMW radar the distinct advantage over other systems of being able to "see" in high atmospheric attenuation situations, such as fog, dust, or heavy precipitation.

The system scans in a raster fashion to produce a 30 degrees in elevation by 90 degrees in azimuth field of view. One disadvantage of MMW radar is that in order to detect wires, the beam must propagate at nearly a 90 degree angle to the wire. One solution to this problem is to increase the azimuth scan to 160 degrees, thereby increasing the chances of striking nearby wires at 90 degrees.

The OASYS Program is testing another active system which employs a carbon dioxide (CO_2) laser radar. Known as a ladar, this laser radar uses a much shorter wavelength than MMW radar. The OASYS program uses a 10.6 micron wavelength. This gives the ladar the advantage of detecting wires which are at oblique angles to the sensor.

Ladars have the disadvantage of being susceptible to high atmospheric attenuation under certain conditions. The CO_2 ladars do not penetrate fog, smoke, or dust nearly as well as MMW radar and in some situations, not at all. Another problem with CO_2 ladars is their degraded ability to detect oblique wires when the wires are wet.

A third system the Army is testing uses a near-IR laser radar. This active system operates at 0.9 microns. These IR radars have been successful at detecting oblique wires, even when they are wet. The systems are lightweight and relatively inexpensive. The major disadvantage of the IR laser is that it operates in the middle of the IR band that poses the greatest hazard to the human eye. One possible solution to this problem is to use a lens to spread the beam. However, this alternative would reduce the effective range of the system.

The fourth system that is being considered in the OASYS program is range-gated active television. This system would employ an array to transmit a pulse. The receiver would use a photocathode or image intensifier to detect the return pulse. The range-gated receiver would be turned on and off to display "snapshots" of images at various ranges. A series of "snapshots" could then be used to step through various ranges. Since light travels so rapidly, the sensor would have to be able to turn on and off extremely rapidly, on the order of a few nanoseconds.

The range-gated television is a lightweight, low-cost method of detecting wires, including oblique wires. However, like the IR laser, it too poses a

serious threat to the human eye. It is also affected by atmospheric attenuation, thereby limiting its effectiveness as an all-weather system.

6.2.4 Low-Light-Level TV

Low-light-level TV (LLLTV) amplifies and displays reflected light, which is basically the same principle that is used for NVG's. LLLTV operates over a spectral region of 0.5 - 0.9 microns with a field of view of approximately 30 degrees vertical by 40 degrees horizontal. Like NVG's, LLLTV suffers from "blooming" effects in the presence of strong light sources. LLLTV's usefulness is dependent upon the size and reflectivity of an object. Hence, wires are not easily seen with LLLTV. LLLTV is affected by atmospheric attenuation and is severely degraded by heavy fog and precipitation.

6.2.5 Synthetic Vision

Synthetic vision is a term used for those systems which produce a synthetic image of the real world. Most of the systems previously discussed may be considered synthetic vision devices. Currently, there are two distinctly different technologies being considered for an FAA funded synthetic vision program. The FAA is supporting a program to evaluate both FLIR and MMW radar for applications in synthetic vision. In the future it is possible that synthetic vision systems, possibly coupled with other avionics, may give the pilot the ability to make "zero-zero" landings under some scenarios. It is also envisioned that synthetic vision may provide the capability for operating VFR under a very wide range of weather conditions. This capability could reduce separation as well as landing aid guidance requirements. Conceivably, guidance information from ILS or MLS might not be required if engineers produce synthetic images accurate enough to allow VFR procedures at all times. However, this is not likely to happen soon.

Synthetic images will most likely be displayed on a HUD. One possible drawback to synthetic vision is that too much information may be displayed to the pilot. HUD symbology overlaid on a FLIR or MMW radar image may prove to be too cluttered. The combination may severely limit the transmissivity of the combiner.

6.2.5.1 Forward Looking Infrared (FLIR)

FLIR systems are passive systems that sense IR radiation emitted by objects to produce an image. The sensors typically operate in one or more of three spectral bands: visible to 1.2 microns (near-IR), 3 to 5 microns (middle-IR), or 8 to 12 microns (far-IR). The prevailing band in use is 8 to 12 microns. FLIR is currently used extensively in military applications and civil law enforcement applications.

Since FLIR operates in the infrared spectral region, it does not depend upon visible light. Therefore, FLIR functions well in both day and nighttime conditions. However, it is not an all-weather system. The primary problem with FLIR systems is that they are affected by atmospheric absorption and scattering. Their performance is degraded by fog or precipitation, especially in instances of heavy fog or precipitation.

6.2.5.2 Millimeter-Wave Radar

MMW radar is an active system which uses millimeter wavelength radiation to synthetically produce an image of the external cockpit environment. MMW radar's distinct advantage over FLIR is that it is not degraded by hydrometeor attenuation. Research using MMW radar has concentrated around 94 GHz. This frequency corresponds to low atmospheric attenuation which provides maximum range and effectiveness. MMW radar is a true all-weather system.

The U.S. Army is evaluating the use of MMW radar as an all weather landing aid. A disadvantage of MMW radar however, is that it has lower degree of resolution than FLIR making its usefulness as a landing air questionable.

6.2.5.3 Concerns For Synthetic Vision Use

Although synthetic vision may allow manual "zero-zero" landings in the future, as well as continuous VFR capability, two particular areas of concern still must be addressed. Both of these concerns have to do with the image displayed to the pilot.

The current design architecture of synthetic vision is to display either FLIR or MMW radar images on a HUD. Overlaid on the image will be HUD symbology. The first concern with this approach is that this amount of information will severely restrict transmissivity of the combiner. This effect could inhibit the pilot's ability to acquire visual cue during instrument approaches or could limit the pilot's ability to scan for traffic.

The second concern with overlaying HUD symbology on synthetically produced images is the difficulty of ensuring that the two separate display techniques are compatible and that they conform to the real world. The concern here is that situations where the two displays are not synchronized with each other will lead to great confusion in the cockpit. For instance, if the runway symbology produced by the HUD is not conformal with the runway image of the synthetic vision display, the pilot will have to choose which image to use for guidance. Also, instances in which the images are conformal with each other but not with the real world may lead to catastrophic results, particularly during very low ceiling and/or low visibility conditions.

One disadvantage to the civil helicopter community of synthetic vision systems is the acquisition cost of the equipment. Although synthetic vision may provide the capability to operate VFR under a very broad range of weather conditions, the cost of the systems may be prohibitive to a large segment of the civil helicopter fleet.

6.3 POLICY AND PROCEDURAL IMPROVEMENTS

Except for those improvements driven by hardware systems improvements, ATC procedures have undergone few changes over the last 20 years that have reduced airborne delays. The emphasis instead, has been on incorporating new technology into the NAS and adjusting policies and procedures to maximize the technology's benefits. Most likely this same trend will continue. Policies

and procedures that incorporate the technological improvements plus other improvements based on community needs are analyzed in the following sections.

6.3.1 Reduced Separation of IFR Aircraft

Reducing IFR arrival delays by decreasing longitudinal radar separation below 3 miles during IFR approaches in IMC is an on-going program for the FAA. Improvements in aircraft position accuracy and update rates due to improved surveillance systems have led many experts to believe a reduction is achievable. From the point of view of some controllers, reduction down to 2 miles between rotorcraft is achievable (reference 53). A few airports currently have reduced separation on final approach down to 2.5 miles and this procedure is described in section 1236 of FAA Handbook 7210.3I and paragraph 5-72 of FAA Handbook 7110.65F. Another program, parallel/converging runway monitor (PCRM), is investigating the concept of conducting simultaneous IFR operations to runways separated by less than 4,300 feet using faster surveillance update rates. For the purposes of this benefit/cost analysis, any further reduction in separation standards between fast moving fixed-wing aircraft is not expected during the time period this study is investigating.

Rotorcraft however, have not been involved in previous investigations of reducing separation standards. Procedures to reduce separation on final between rotorcraft and in-trail aircraft based on existing procedures,appear implementable. This possibility is discussed in section 8.1.6.

6.3.2 Increase in Instrument Approach Procedures

FAA navigation enhancements and approach procedure development policies will likely allow instrument approaches to become more readily available to helicopter operators. LORAN-C approaches in particular, may provide a low cost and easily certifiable nonprecision instrument approach system over the next 5 to 10 years.

GPS nonprecision instrument approaches provide a far term (year 2000) alternative to LORAN-C nonprecision approaches. Predictable horizontal accuracy using uncorrected GPS signals is greater than that achievable with LORAN-C. Differential GPS has promise to permit precision-type approaches to levels approaching Category I ILS capability.

Microwave landing systems provide capability for precision instrument systems at helipads. In addition, their curved approach adaptability makes MLS well suited for many city-center locations. Variable glide path angles and different approach tracks should enable both rotary-wing and fixed-wing aircraft to make independent approaches to the same airport utilizing the same approach aid. In addition, the technology may allow the establishment of a new nominal decision height of 150 feet. In short, the versatility of the MLS offers great potential for developing a new generation of rotary-wing/fixed-wing approach and department procedures in terminal airspace.

6.3.3 Traffic Alert and Collision Avoidance System (TCAS)

The implementation of TCAS will assist pilots with VFR separation in low and medium density airspace. The TCAS equipment is installed aboard the aircraft and interrogates aircraft transponders in the vicinity. Based upon replies, TCAS II and III computers recommend if an altitude or course change is required to avoid the other aircraft.

Since rotorcraft sometimes operate VFR in atmospheric conditions of low ceiling or reduced visibility, TCAS could provide valuable separation information from both aircraft and stationary obstructions. In better weather, it's less certain whether rotorcraft would benefit from TCAS. Relative to airplanes, rotorcraft operate at slower airspeeds and rotorcraft cockpit designs typically enable larger fields of view. Both differences enable better traffic avoidance. Another important factor is that TCAS will likely be expensive. Minimum TCAS equipment will consist of a Mode S air traffic control transponder, an interrogation system, a computer, and a display screen. Due to the costs, TCAS will be more cost effective for larger, more expensive commuter and corporate rotorcraft than for smaller rotorcraft.

6.3.4 Parallel/Converging Runway Monitor (PCRM)

The objective of the PCRM program is to establish the technical characteristics for a future radar runway-monitoring system that will permit more efficient utilization of closely spaced and converging runways during instrument conditions. The PCRM study was initiated in 1987 under a program entitled Parallel Runway Monitor (PRM) and gradually evolved from a study designed solely to improve IFR parallel runway operations, to one which can be applied to converging operations and other multiple approaches.

Different radar system designs are currently undergoing tests at Raleigh-Durham, NC and Memphis, TN. The Raleigh-Durham test uses a fixed phased-array antenna, while Memphis is utilizing a pair of open-array beacon antennas mounted back to back. Both systems appear to have the potential of increasing airport access during instrument weather conditions for both rotary- and fixed-wing aircraft. Action should be taken to ensure that any potential for providing additional airport access for rotorcraft is not overlooked during this test program.

6.3.5 Point-In-Space Approaches

If rotorcraft are ever going to gain equal access with fixed-wing aircraft to airports, without interfering with the fixed-wing traffic flow, new innovative approach procedures must be developed and adopted. VFR and SVFR flight environments appear to provide the best solution to this access problem, but the difficulty of transitioning from an instrument to a visual environment continues to pose a significant problem. The concept of a point-in-space approach, if properly developed, seems to offer the simplest and most logical method of providing this transition and ultimately permitting rotorcraft to help relieve some of the delay problems. A point-in-space approach has the potential to provide the key ingredient for transitioning

rotorcraft from an IFR world to a visual environment and provide the latitude for tailoring airspace to fit the needs of both fixed- and rotary-wing aircraft with a minimum of expense.

Today's operating procedures require the use of a published instrument approach to make the IFR-VFR transition. Existing methodology forces both fast and slow aircraft to be funneled into a single approach path, leading to a slow down of traffic and delays. The end result is saturation of the approach control airspace. Separate, non-interfering (or minimally interfering) instrument approach procedures for fixed- and rotary-winged aircraft offers the best opportunity for alleviating this airspace saturation problem.

6.3.6 Rotorcraft-Only Standard Terminal Arrivals (STAR) and Standard Instrument Departures (SID) Procedures

STAR's provide pilots with the ability to transition between an outer fix, or arrival waypoint in the en route structure, to the terminal area and the airport. Conversely, SID's depict routes from the airport through the terminal area to the en route structure. They permit pilots to perform their own navigation while reducing controller workload.

Conceptually, a rotorcraft STAR could be developed that originates at a feeder fix in the en route environment, and incorporates VOR/DME, RNAV, and/or LORAN-C routing to a final approach fix for an independent approach to the airport. Alternatively, the routing could lead to an approach fix for a point-in-space approach. The approach would terminate in visual conditions at the edge of the airport traffic area or provide entry to the VFR route structure at points easily identifiable by landmarks.

In busy terminal areas, dedicated rotorcraft SIDs would be useful in segregating departing rotary-wing aircraft from the standard departure routes of fixed-wing aircraft. The SID could originate at the heliport/vertiport and not from the end of a runway. The helicopter's initial departure courses on the SID should be greater than 45 degrees from the main traffic pattern of arriving or departing aircraft to ensure adequate IFR separation standards. At low activity airports, exclusive rotorcraft SID's and STAR's may not be necessary unless there are significant rotary-wing/fixed-wing traffic conflicts.

6.4 SUMMARY OF NAS ENHANCEMENTS

The preceding paragraphs of this section have discussed enhanced ATC facilities derived from the FAA's NAS Plan/Capital Improvement Plan effort, enhanced avionics/visionics carried aboard the aircraft, and enhanced/enlighted ATC policies and procedures. In summary, all of these enhancement approaches have considerable merit. In addition, when integrated into an overall enhancement program, considerable benefits to both rotary- and fixed-wing users can be achieved. The specific benefits are described in detail in section 8.0.

7.0 RADAR AND COMMUNICATIONS COVERAGE

Radar and communications facilities are situated to provide maximum coverage in areas of greatest operational need. Since fixed-wing aircraft operate at higher altitudes, the needs of these aircraft, for the most part, are met by established radar and communications facilities. However, the same is not necessarily true for rotorcraft. Rotorcraft typically operate at much lower altitudes than fixed-wing aircraft. Rotorcraft stage lengths are typically of short duration, and they do not require higher altitudes for improved performance. This section analyzes radar and communications coverage for the 50 locations based on a line-of-sight analysis.* Locations of radar and VHF communications sites as conceived in supporting documentation to the NAS plan were used to evaluate coverage. Operator inputs from telephone interviews were also used to determine areas which lack adequate low-level radar or communications coverage.

7.1 RADAR COVERAGE

Future radar site locations were obtained from the National Airspace System Specification (reference 55). This specification contains the latitude and longitude of all radar sites, including terminal and en route radars, that are expected to be operational by the year 2000, termed the NAS end-state. Figures 11 and 12 depict the locations of NAS end-state radar sites throughout CONUS and Alaska, respectively. These figures show that for the 50 locations chosen in this study and particularly for the Northeast Corridor, the Gulf Coast, and southern California, there will be a relatively high concentration of radar sites as compared to other portions of the United States.

In order to determine radar coverage for the study sites, it was first necessary to determine the lowest altitude at which radar coverage would be desired. In telephone interviews, operators stated that their operating minimums varied depending on factors including mission type, time of day, and distance of flight. These VFR minimums varied from a 1,200 foot ceiling and 1 mile visibility to "clear of clouds." Many operators indicated that they use a 500 foot ceiling and 1 mile visibility as their operating minimums. Allowing for a 100 foot clearance below this ceiling for safety purposes places operations at 400 feet. Therefore, 400 feet was chosen as the minimum altitude for desired radar coverage to assist VFR and SVFR operations.

For en route IFR flights, minimum altitudes must be 1,000 feet above the highest obstacle in nonmountainous areas and 2,000 feet above the highest obstacle in designated mountainous areas. This obstacle clearance requirement is not likely to change. Therefore, a reasonable surveillance coverage altitude that would satisfy all en route IFR requirements would be 1,200 feet AGL in nonmountainous terrain and 2,200 feet AGL in mountainous terrain. This assumes the highest vegetation and manmade obstacles in the vicinity are about 200 feet.

* Note: More detailed maps that take into account terrain masking will be presented in the final report.

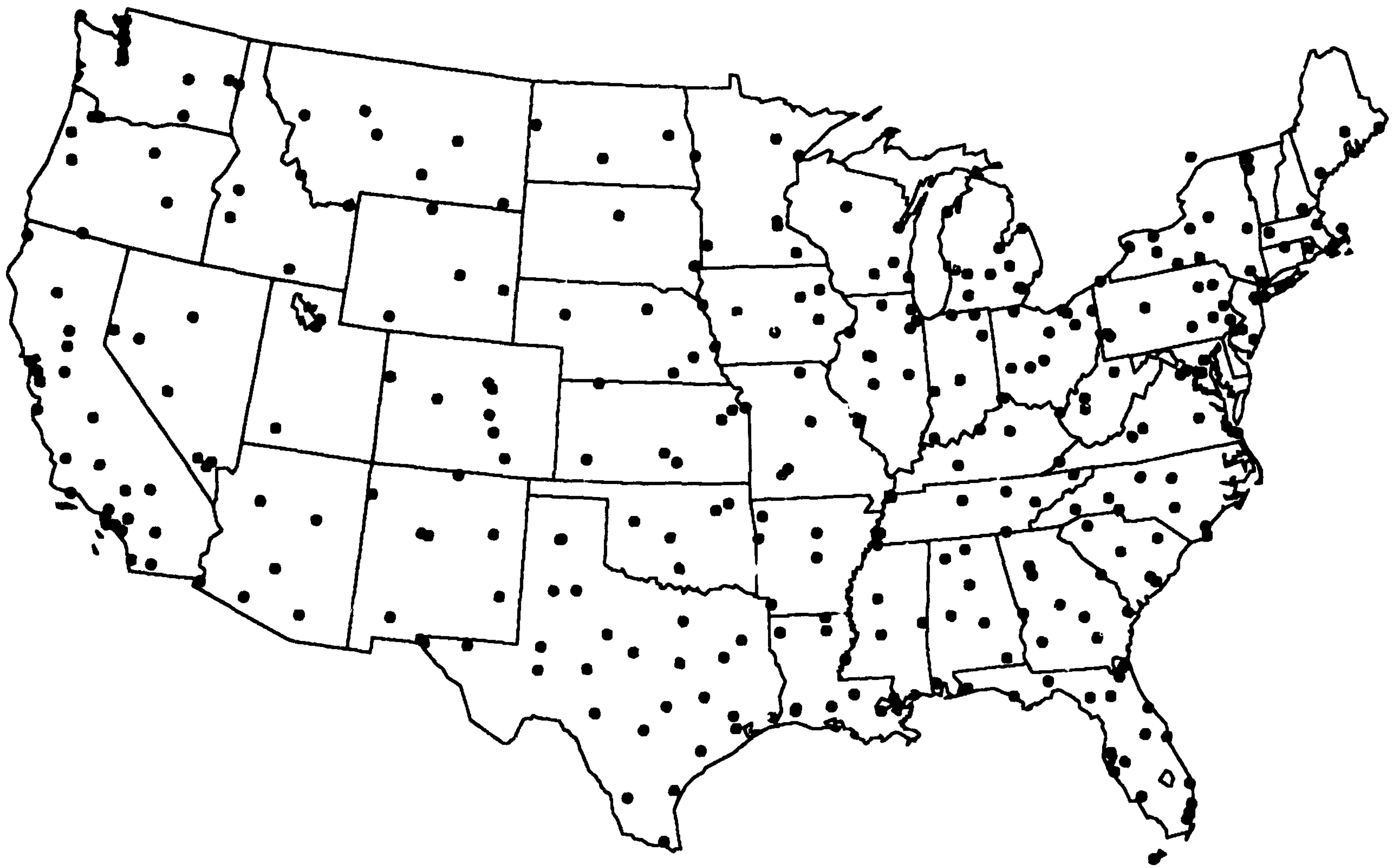


FIGURE 11 NAS END-STATE RADAR SITES IN CONUS

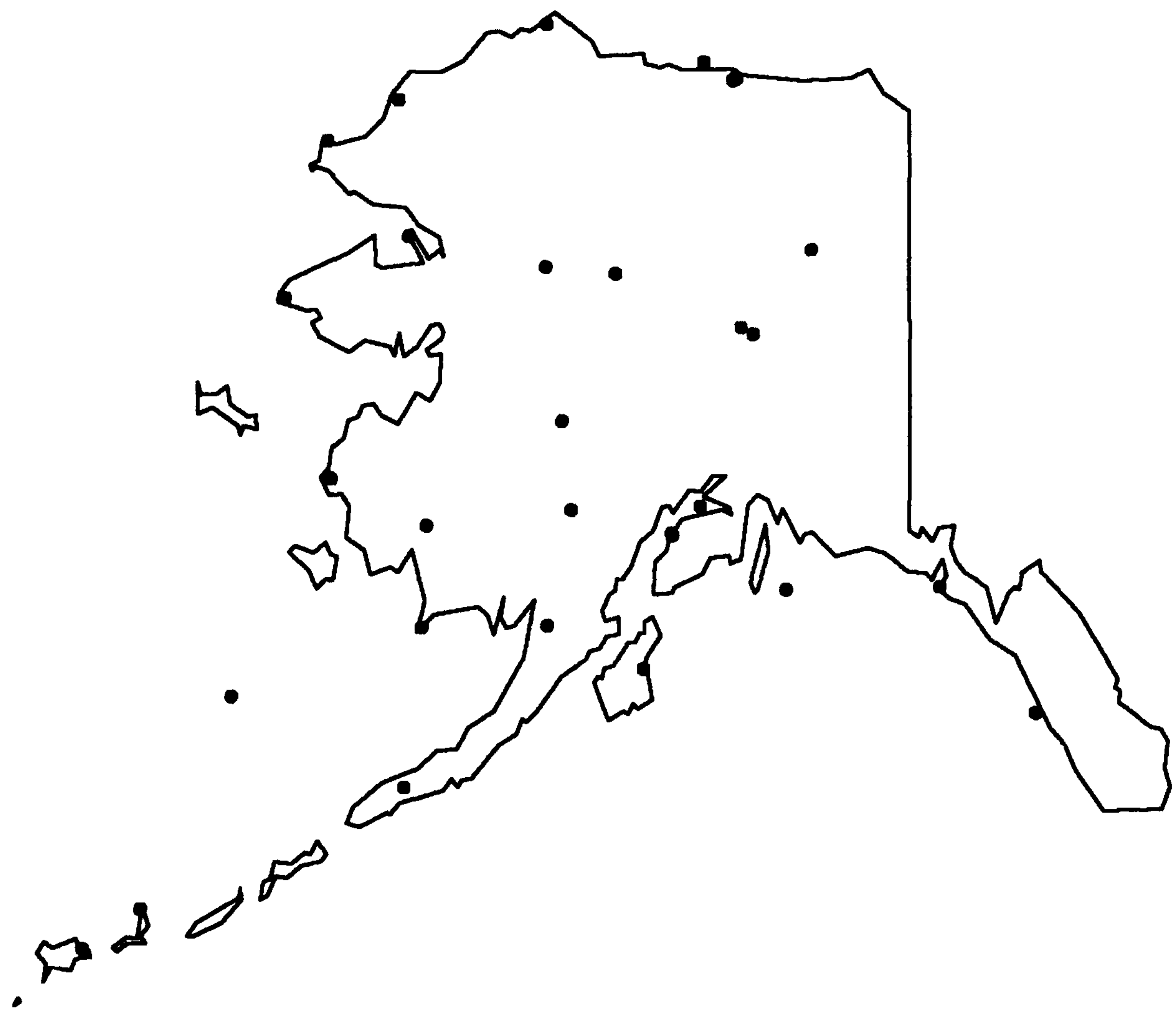


FIGURE 12 NAS END-STATE RADAR SITES IN ALASKA

For the most part, VFR rotorcraft missions are not hindered by a lack of surveillance coverage. Therefore, radar coverage down to 400 feet would not help satisfy operational requirements for VFR rotorcraft. However, it would add a degree of safety to these operations if flight following were requested. Surveillance coverage can aid ATC service to SVFR rotorcraft in high-activity control zones. Separation between SVFR traffic and IFR traffic is the controller's responsibility and radar provides the only means to guarantee adequate separation until visual separation is assured. Rotorcraft operators reported experiencing delays in a nonradar control zone because of the need to hold outside of the control zone until other IFR aircraft were clear. A few operators reported delays of 20 minutes or more while operating in a control zone in a nonradar environment (see section 5.8.3.4).

Low altitude IFR operations can be significantly hindered by the lack of surveillance coverage. Minimum separation requirements in a nonradar environment are 20 nautical miles or timed separations of 10 minutes. This requirement greatly reduces airspace capacity for IFR operations. The most notable area where lack of surveillance causes IFR rotorcraft delays is in the Gulf of Mexico.

Low altitude surveillance gaps are also observed over land in both low and high traffic areas. In high traffic areas, the adoption of tower en route control for the handling of low altitude traffic has limited radar coverage to only that which is provided by terminal radar systems. As a result surveillance gaps between terminal areas can occur. To maintain proper separation standards in these areas, controllers must either direct the IFR aircraft to a higher altitude or apply nonradar separation standards.

A formula which accounted for curvature of the earth as well as radar antenna height was used to determine radar coverage at 400 feet. Radar locations as well as antenna heights were obtained from the NAS System Specification (reference 6). Accounting only for the earth's curvature and radar antenna height provides a rough approximation of radar coverage. Radar is basically limited by line-of-sight. Objects between the radar and the target will block the radar signal and mask the target. A more accurate presentation of coverages, one that takes into account terrain masking, is presented in the final report. These more detailed coverages were not presented in this report due to time and computer availability considerations.

Figures 13 and 14 show the calculated radar coverage over the United States at 400 feet for NAS end-state. Since masking by terrain or buildings was not considered, these figures represent the optimum coverage that could be expected at 400 feet and not what actually exists. It should be noted that as the altitude of desired coverage increases, the radar coverage area expands. In other words, a radar coverage map developed for 2,000 feet would show a larger area of coverage than the 400 foot map.

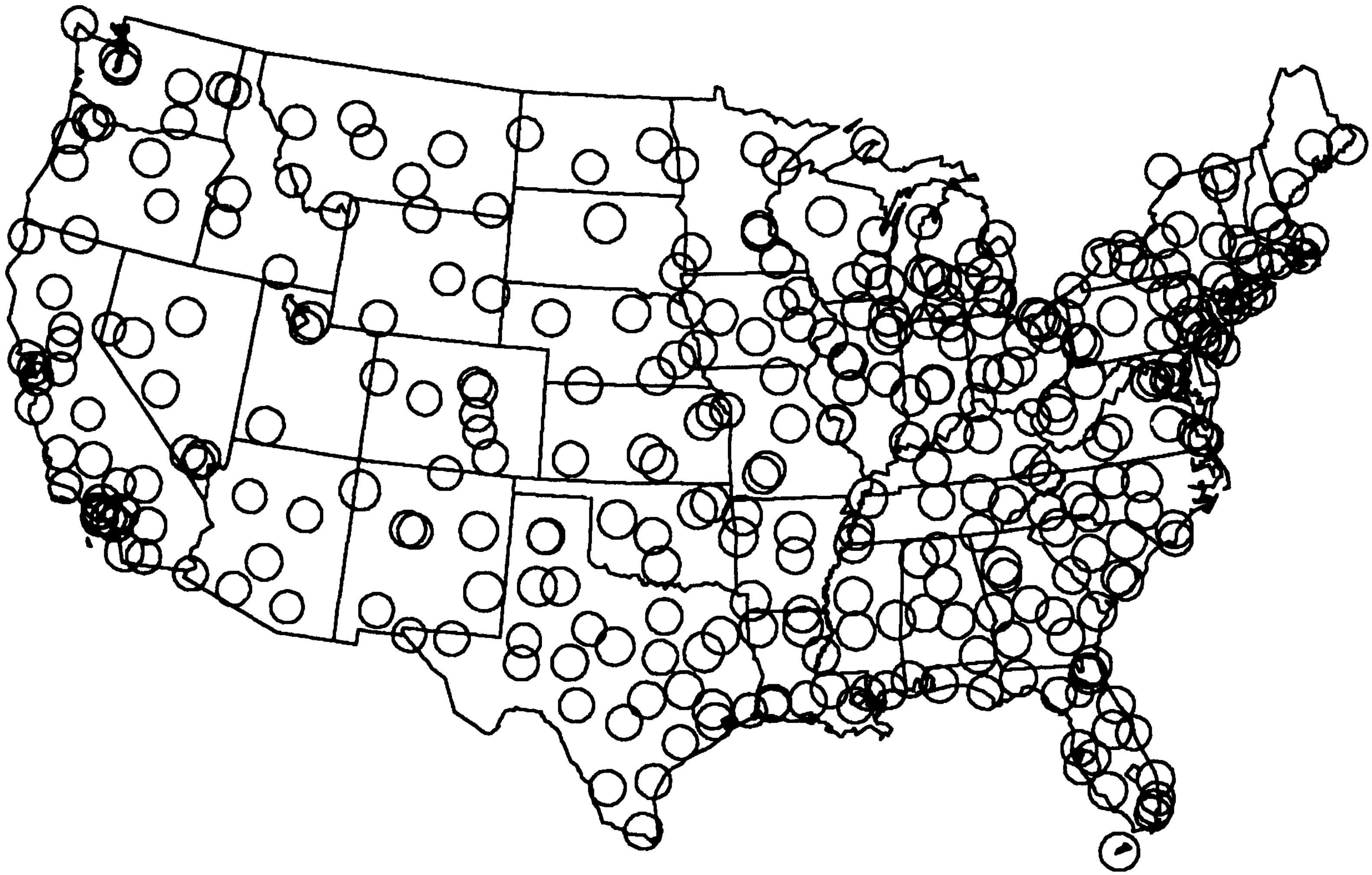


FIGURE 13 NAS END-STATE RADAR COVERAGE AT 400 FEET, CONUS

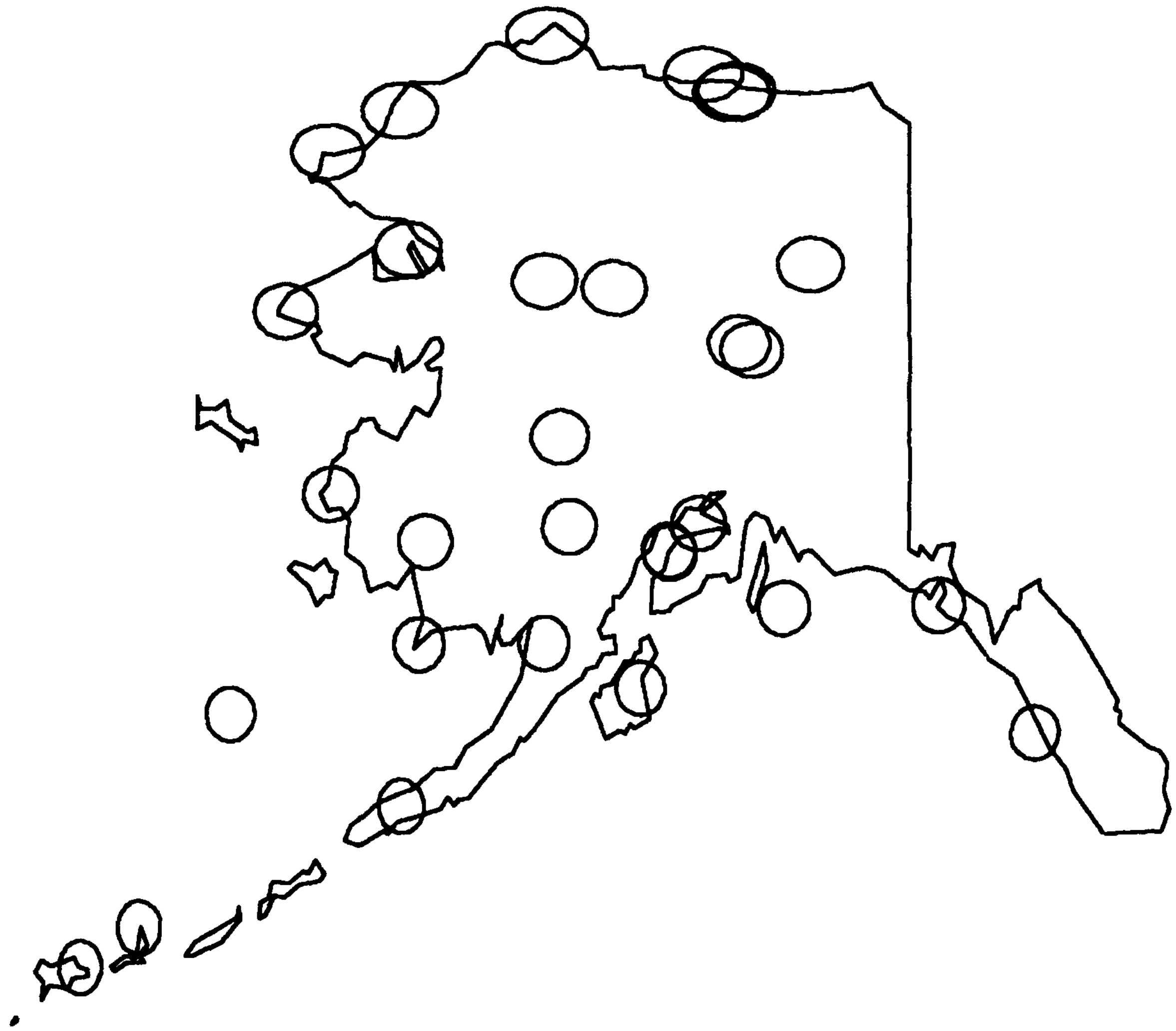


FIGURE 14 NAS END-STATE RADAR COVERAGE AT 400 FEET, ALASKA

Figures 15 through 18 show the calculated radar coverage at 400 feet altitude over the 50 selected locations. These figures show that most of the sites selected for the study do have good surveillance coverage down to 400 feet. Sites located within the Northeast Corridor and in southern California, where significant percentages of the total number of helicopter operations in the United States occur, are well covered by the current and planned radar sites. However, several other locations lack full coverage at this altitude. This is particularly true for the Gulf Coast sites (see section 5.3.3.2). Radar sites along the Gulf Coast are land-based and their coverage at 400 feet does not extend very far out over the Gulf waters. However, offshore rotorcraft operations routinely extend over 100 miles from the coast line. Currently, IFR approaches and departures in this area are conducted using nonradar separation standards. Low-altitude en route IFR operations also experience delays resulting from inadequate radar coverage.

Other locations that lack full radar coverage within the boundaries of the study sites include areas to the east of Seattle, WA; to the east of Dallas, TX; south of Provo, UT; and northeast and southwest of Atlanta, GA. Although several study sites do lack complete radar coverage down to 400 feet, rotorcraft operators in the telephone interviews reported very few problems resulting from a lack of radar coverage within their operating areas. One exception to this was the offshore operators, who indicated that surveillance at lower altitudes over the gulf would allow increased operations as well as providing an added margin of safety. The Northeast Corridor was also noted by operators as needing additional low-level coverage. The main concern for these operators occurs when icing conditions exist. East-west gaps in low-level radar coverage across Connecticut often result in IFR helicopter flights being flown at higher altitudes. At times these altitudes place rotorcraft at levels where icing conditions exist. Therefore, these flights must be delayed or canceled. If low-level surveillance was available, operators would be able to fly at lower altitudes where icing occurs less often.

7.2 SITE SPECIFIC RADAR COVERAGE GAPS

In the telephone interviews, operators were asked specifically if there were any gaps in surveillance coverage in their operational areas. This question was important due to the fact that radar masking by terrain features, or screening by structures, was not taken into account for when calculating surveillance coverage. Although radars in most major metropolitan areas are screened somewhat by the local skyline, only one site reported having significant delays due to a lack of radar coverage in controlled airspace. These delays occurred while trying to transit through a control zone (see section 5.8.3.4). As previously mentioned, providing radar coverage in control zones would allow for reduced separation criteria and thereby reduce delays. However, providing additional radar sites for individual problems is not always a practical solution. The total number of SVFR helicopter operations during these times may not justify the expense of additional radar facilities. Alternate solutions for SVFR helicopter transits through nonradar control zones may be more practical (see section 6.3).

Several operators did report areas, primarily in the vicinity of large metropolitan centers, where gaps in surveillance coverage occur. These gaps

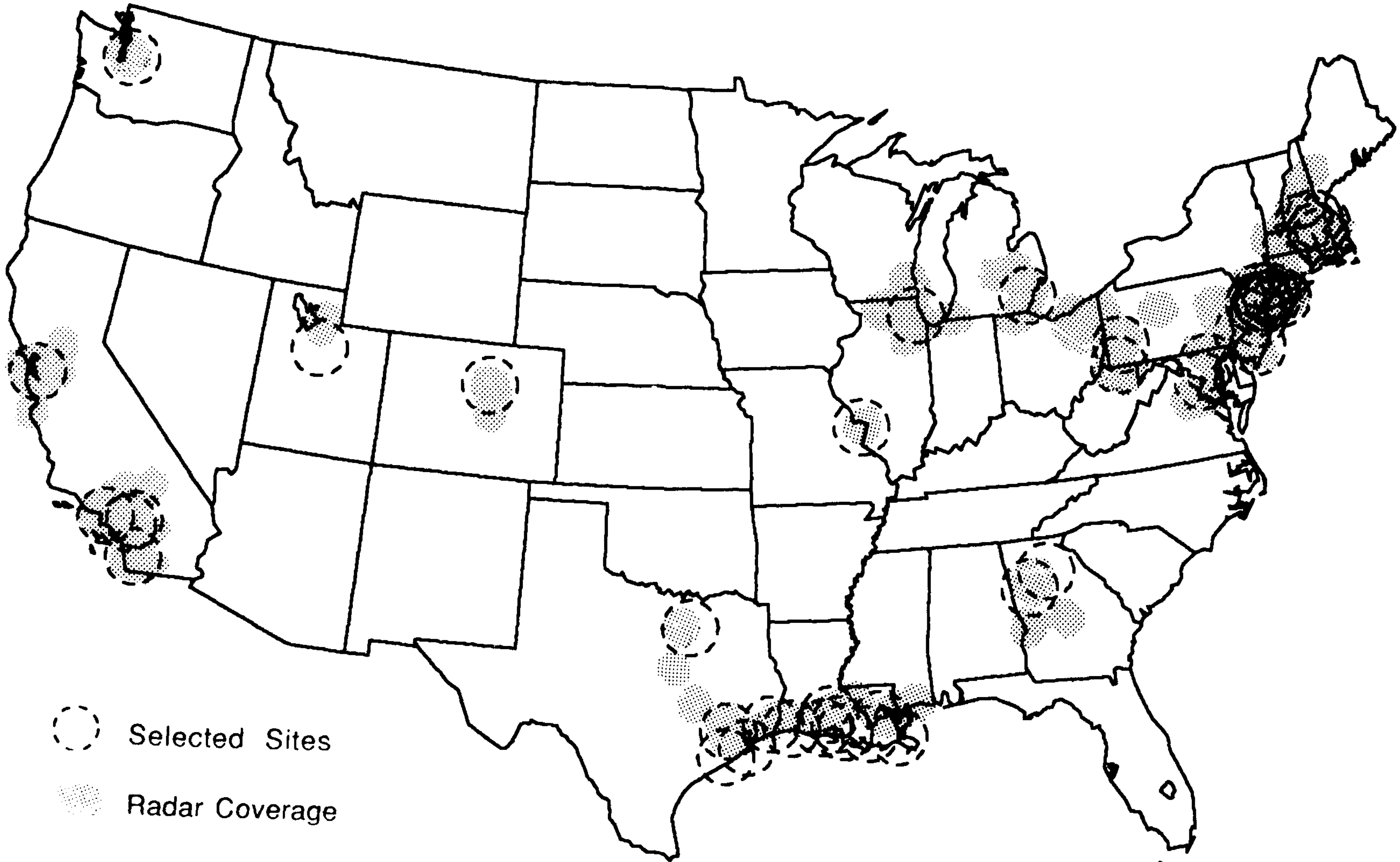


FIGURE 15 RADAR COVERAGE AT 400 FEET OVER SELECTED SITES, CONUS

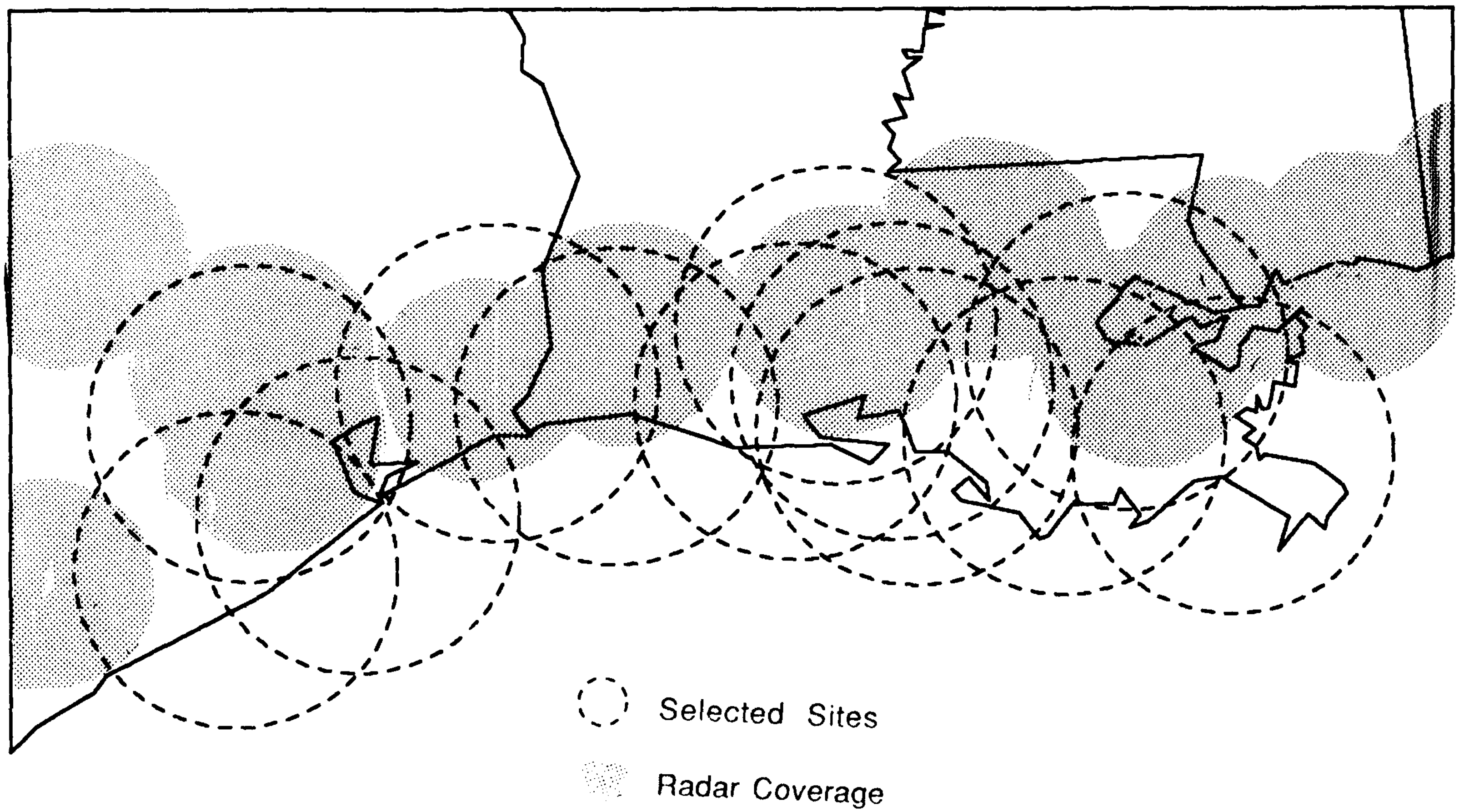


FIGURE 16 RADAR COVERAGE AT 400 FEET OVER SELECTED SITES, GULF COAST

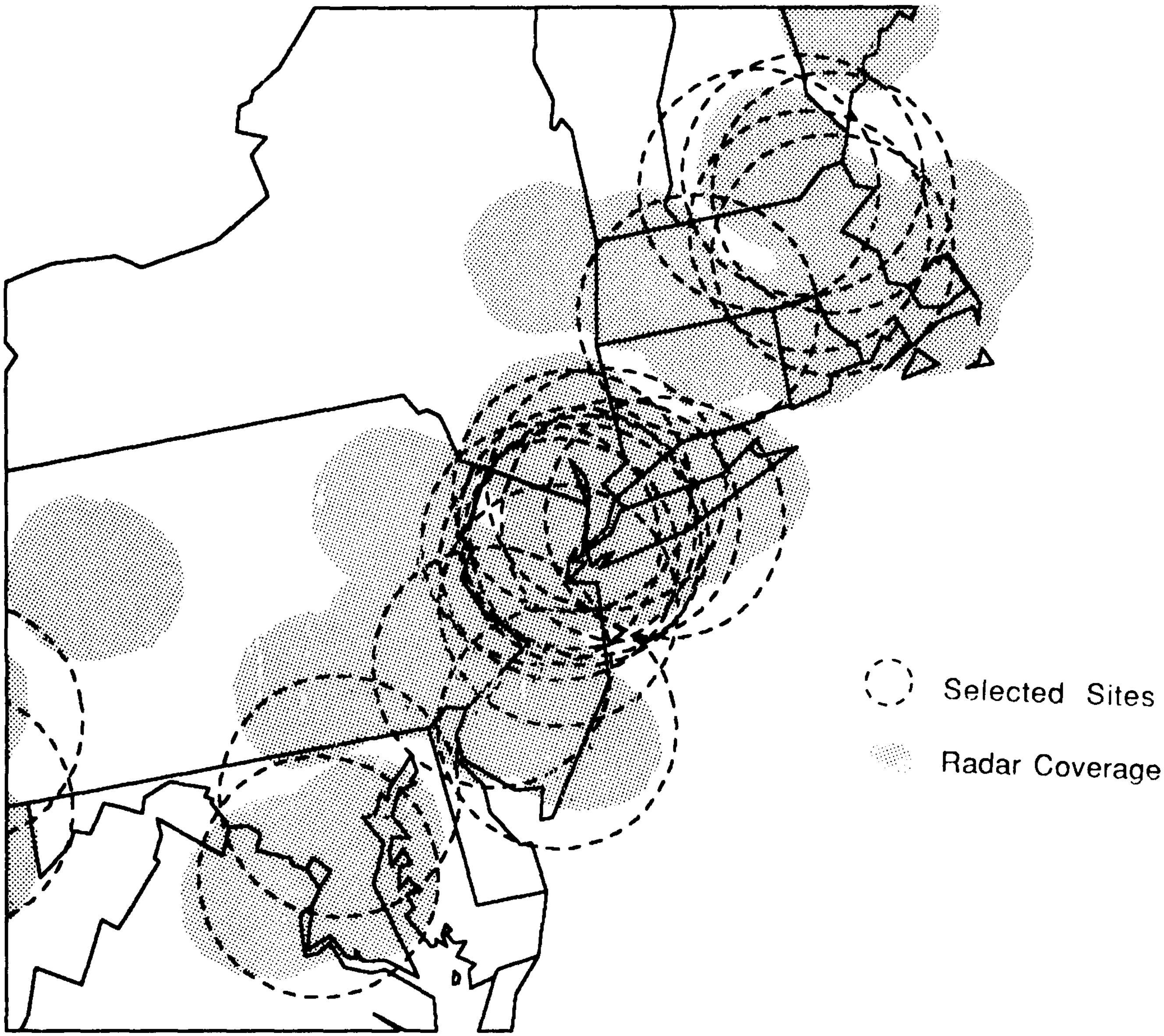


FIGURE 17 RADAR COVERAGE AT 400 FEET OVER SELECTED SITES, NORTHEAST

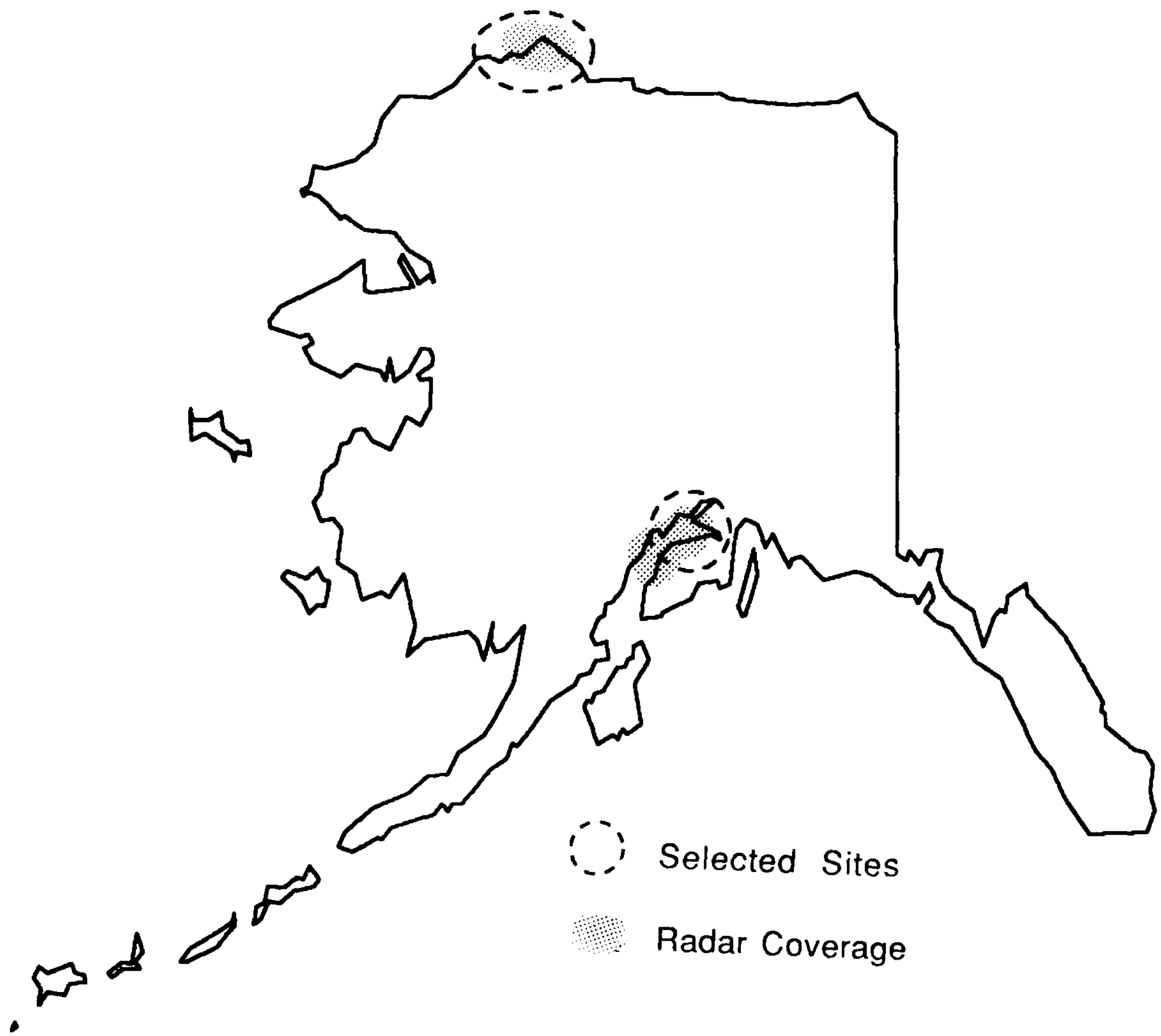


FIGURE 18 RADAR COVERAGE AT 400 FEET OVER SELECTED SITES, ALASKA

are caused by tall buildings or building skylines located in city centers which screen the line-of-sight radar coverage. One example of this was reported in the Boston area. Operators reported gaps in both surveillance and communications in and near downtown Boston. Since both radar and communication gaps were reported in Boston, this city is used in the following paragraphs to illustrate the types of problems that may be experienced in metropolitan areas.

Operators reported that an area to the west of downtown Boston lacks low-level radar coverage from Logan International Airport. Figure 19 was developed from operator responses and shows the area, locally referred to as the "blind spot," where radar coverage from Logan Airport is basically limited to 1,000 feet AGL and above. Traffic entering the TCA (8 mile radius from Logan Airport) must request permission from Logan Tower prior to entering the TCA. Because the "blind spot" makes it difficult for radar to acquire aircraft operating at low altitudes, rotorcraft operators typically avoid this area when approaching Logan Airport. Although this low-altitude radar gap does exist, operators have not found it to be of major consequence to them or their operations.

Operators have also reported low-altitude surveillance coverage gaps near other major city centers. Locations on the west side of Manhattan, downtown Los Angeles, and downtown Chicago also have areas which lack low-altitude radar coverage. However, as in the case of Boston, none of the operators in those areas consider the surveillance gaps to be of any major consequence or concern to their operations.

7.3 COMMUNICATIONS COVERAGE

Figures 20 and 21 show current and planned VHF air/ground communications facilities for the United States. It is apparent from these figures that the 50 locations chosen for this study appear to be relatively well covered in terms of VHF communications facilities. Coverage rings to show communications coverage at 400 feet were not drawn because of the sheer number of communications outlets. Coverage rings would provide a very cluttered depiction and, as can be seen from figures 22 through 25, the 50 selected sites are well covered by communications outlets.

Telephone interviews concerning communications coverage produced very similar results to those concerning surveillance coverage. There were very few areas within the 50 study sites that presented any major difficulties to operators. However, there were areas that did lack communications coverage down to 400 feet. As was the case with radar coverage, most of those areas were located in major city centers and were related to masking caused by the local skyline. Here again, Boston provides an example of masking by its local skyline. Figure 26 outlines an area southwest of Logan International Airport where rotorcraft, operating below 1,000 feet AGL, report having difficulty receiving transmissions from controllers at Logan. Operators reported that many times transmissions are erratic at low altitudes in this area. This does present somewhat of a problem for pilots when they are trying to enter Logan's TCA. However, rotorcraft operators have adjusted to the situation by either

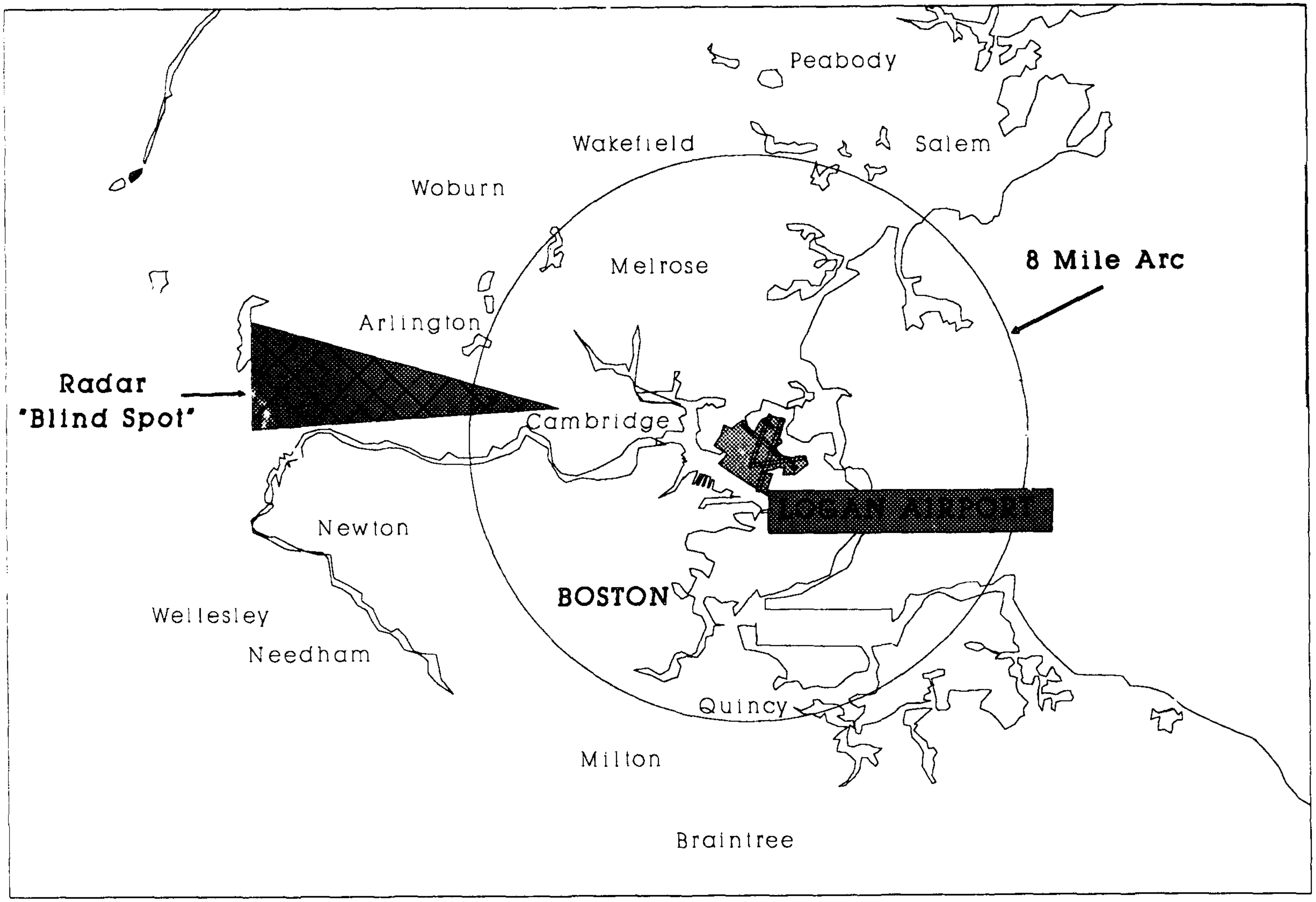


FIGURE 19 LOW ALTITUDE RADAR "BLIND SPOT" (BOSTON AREA)

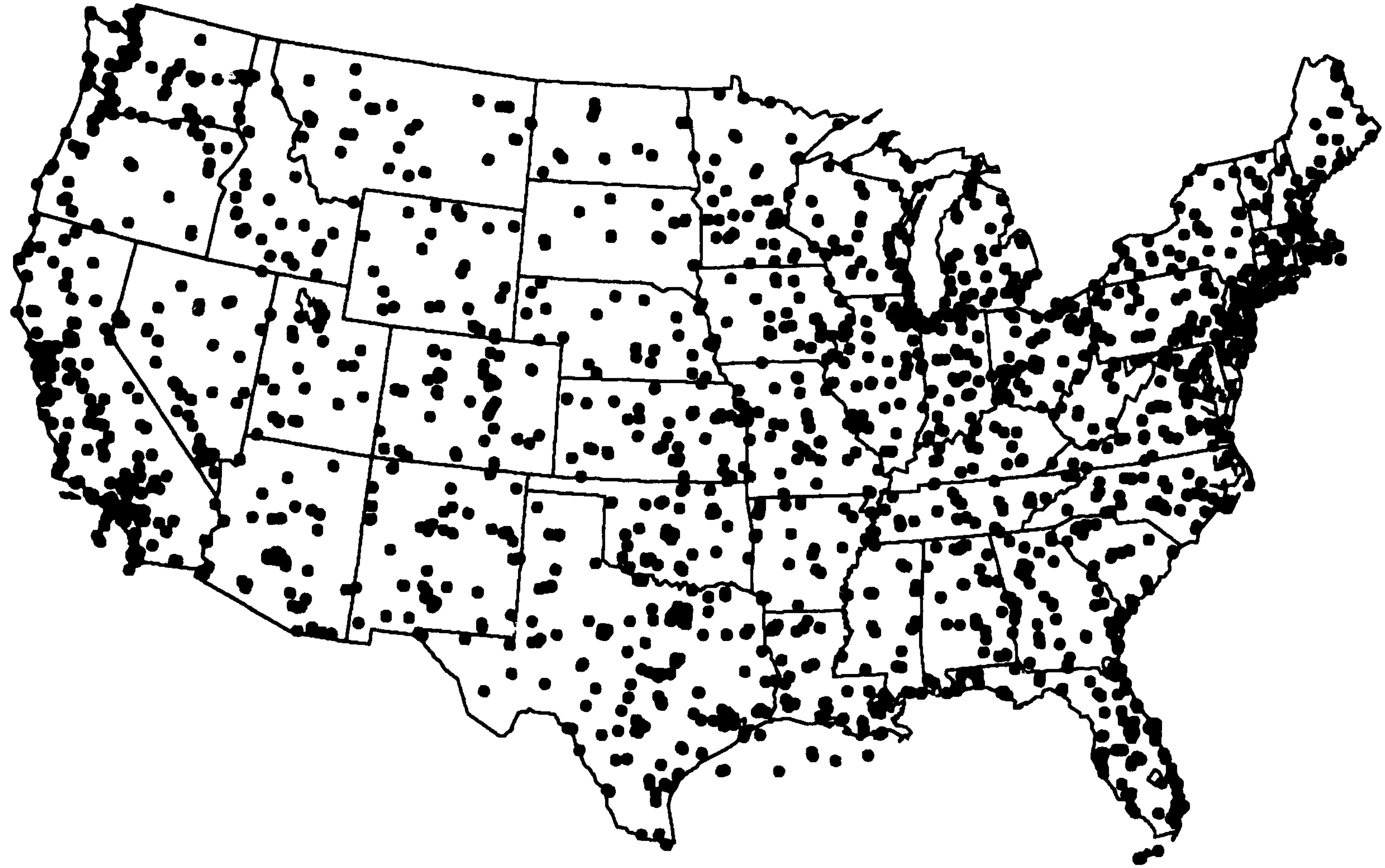


FIGURE 20 VHF COMMUNICATIONS SITES, CONUS

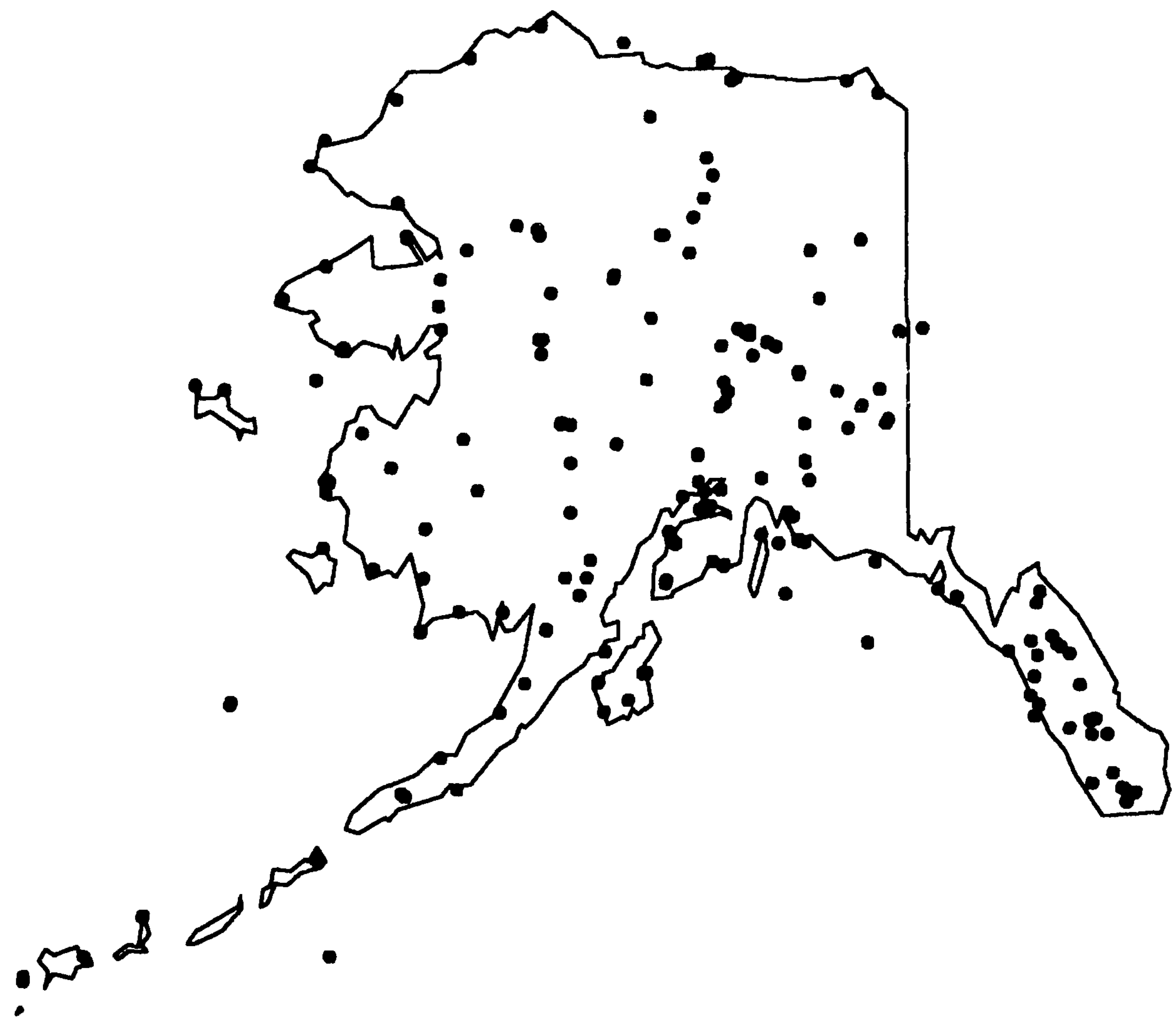


FIGURE 21 VHF COMMUNICATIONS SITES, ALASKA

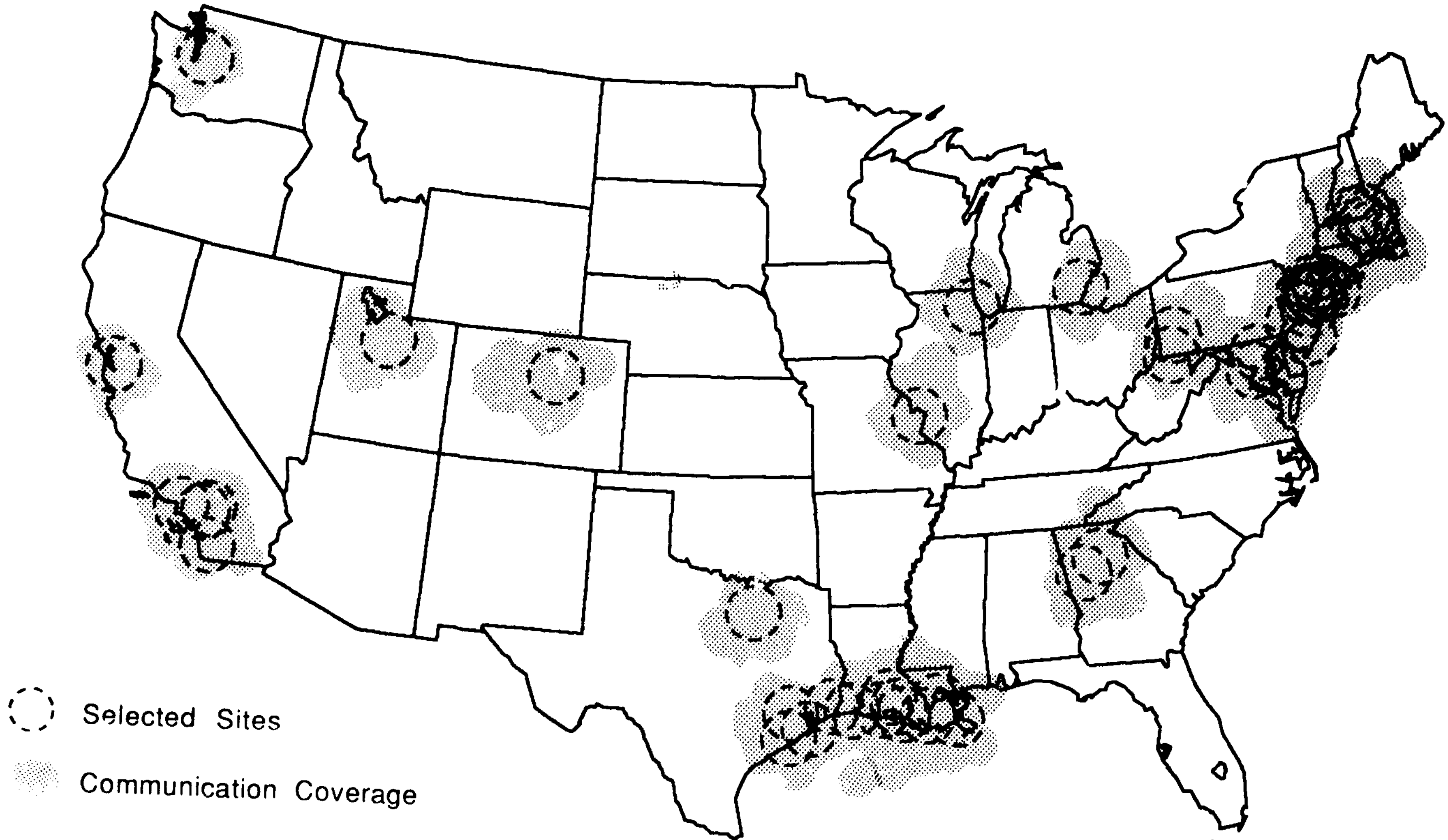


FIGURE 22 VHF COMMUNICATIONS COVERAGE AT 400 FEET OVER SELECTED SITES, CONUS

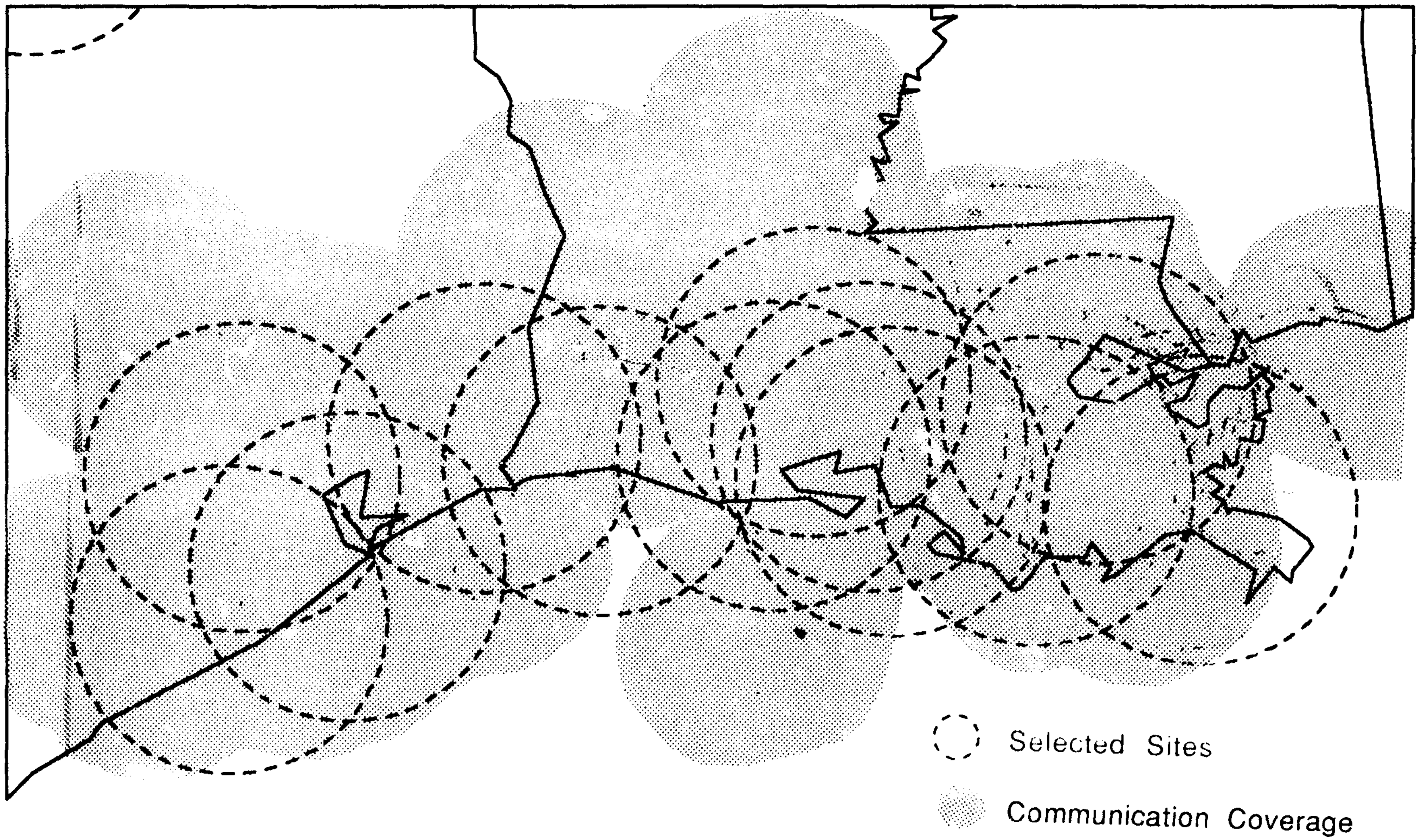


FIGURE 23 COMMUNICATION COVERAGE AT 400 FEET OVER SELECTED SITES, GULF COAST

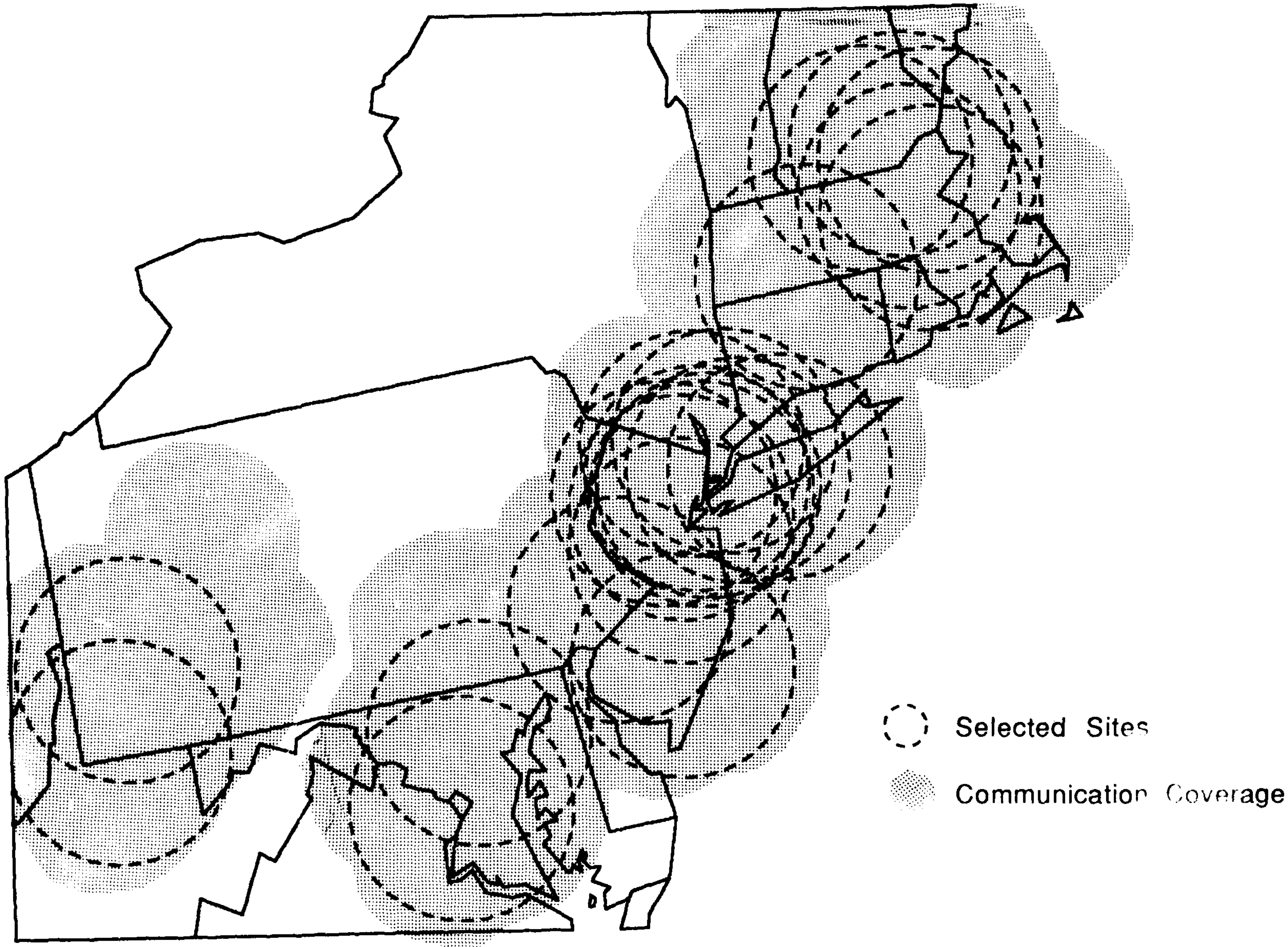


FIGURE 24 COMMUNICATION COVERAGE AT 400 FEET OVER SELECTED SITES, NORTHEAST

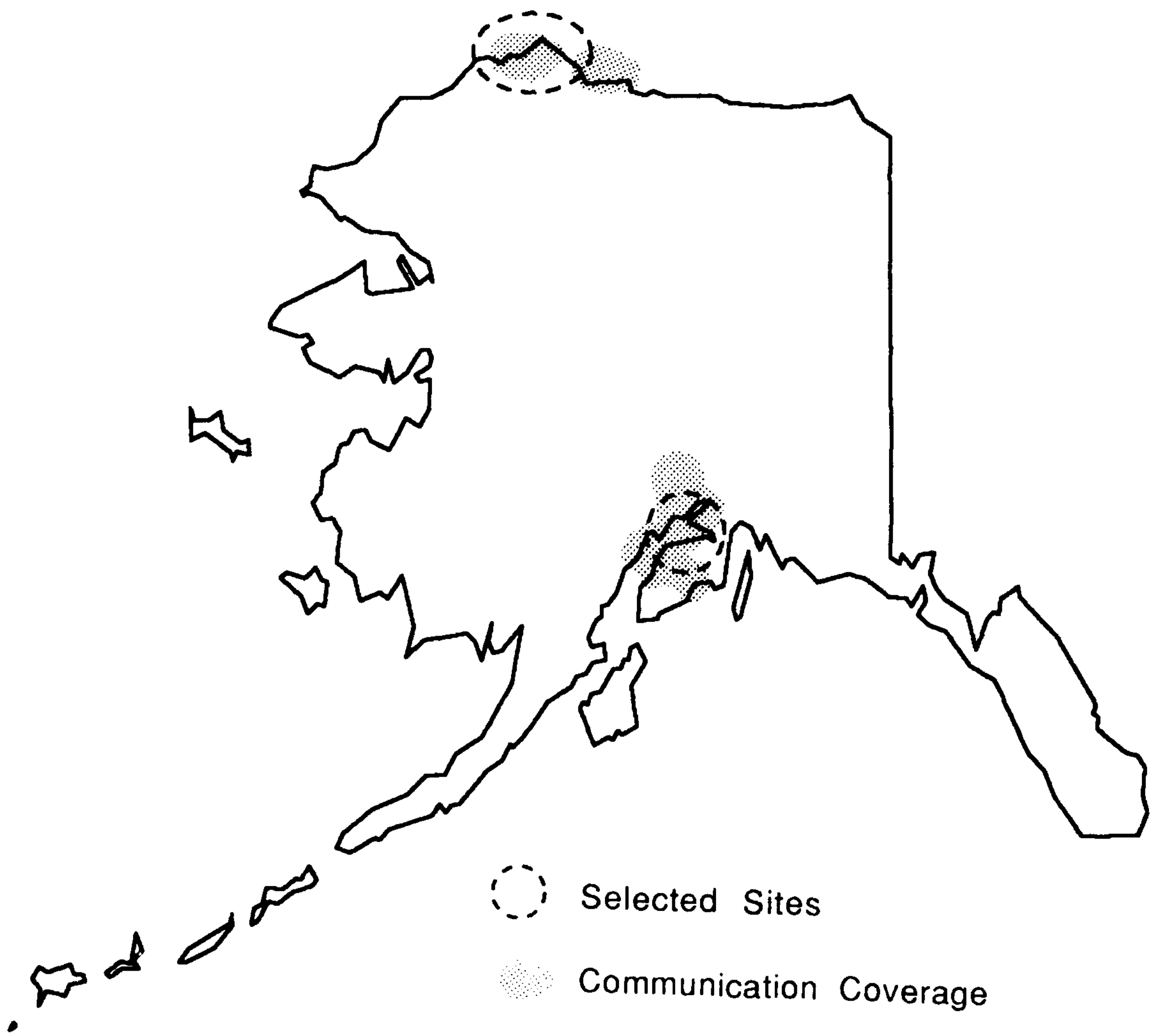


FIGURE 25 VHF COMMUNICATIONS COVERAGE AT 400 FEET OVER SELECTED SITES, ALASKA

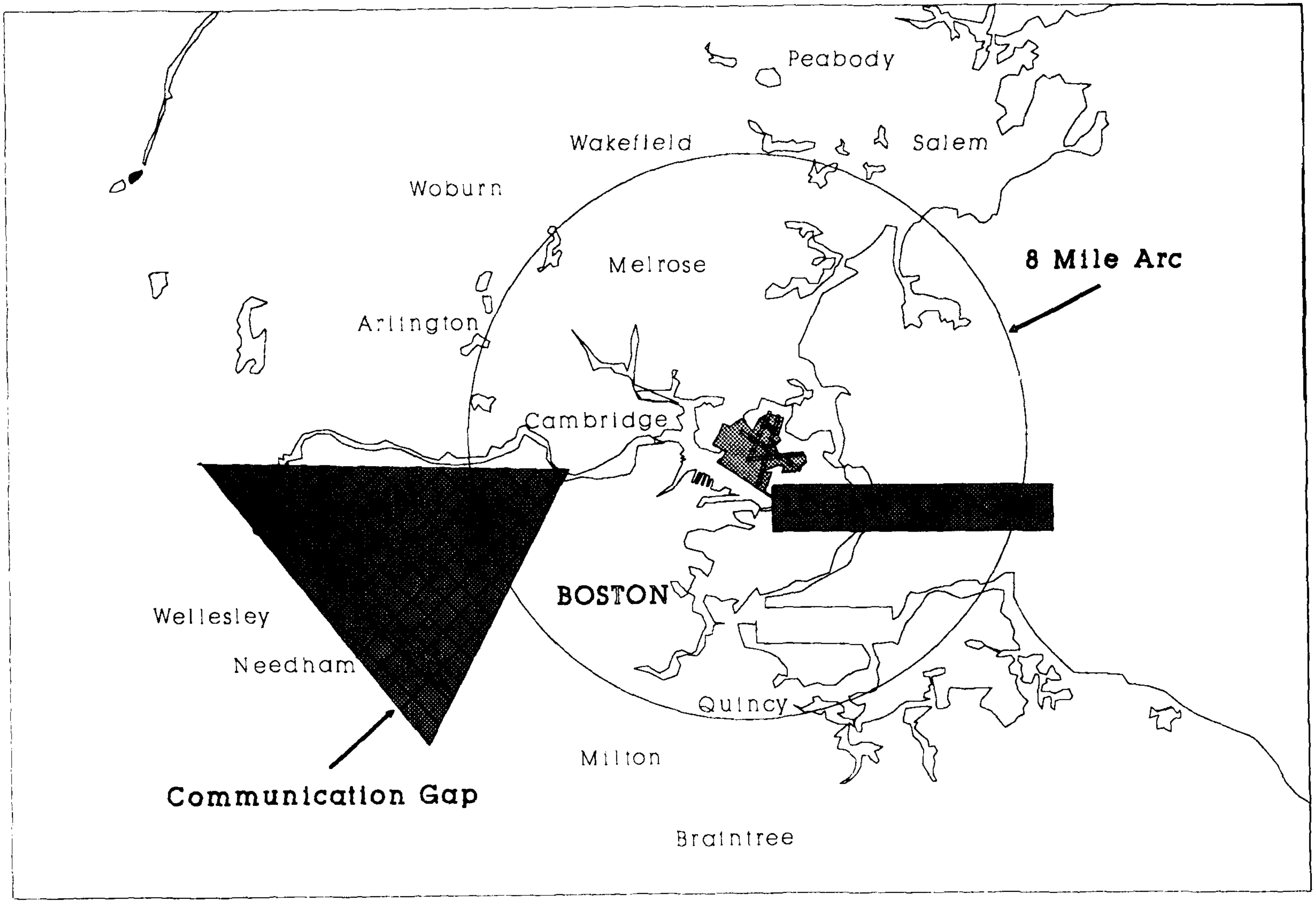


FIGURE 26 LOW ALTITUDE COMMUNICATIONS GAP (BOSTON AREA)

operating at higher altitudes when possible or calling controllers further out from Logan. Operators in other major cities, including New York, Oakland, Chicago, and Washington, DC, also reported areas where there was a lack of low-level communications capability. Again, none of the operators reported any major problems because of these communication gaps in their operating areas. However, as IFR flights become more prevalent for rotorcraft missions, more gaps in low level communication coverage will likely be identified.

The other area which lacked blanket low-level communications coverage was over the Gulf of Mexico. At locations well offshore, operators reported that there was a lack of coverage below 4,000 feet on the established north-south routes. Those wishing to fly IFR on those routes, or desiring VFR flight following in that area, had to be above 4,000 feet to be able to communicate with ATC.

7.4 SUMMARY

Communications and surveillance coverage deficiencies were analyzed as they affect both VFR and IFR rotorcraft operations. En route VFR rotorcraft operations have communications and surveillance requirements as low as 400 feet AGL in terminal areas. These requirements are largely satisfied, since appropriate communications and surveillance equipment is usually centrally located within the terminal area and line-of-sight coverage is adequate. IFR rotorcraft en route operations can require communications as low as 2,000 feet (and in a few areas as low as 1,000 feet) AGL, and coverages are adequate in most areas where aircraft traffic activity levels dictate a need. A noteworthy exception is in the Gulf of Mexico off the coasts of Louisiana and Texas where significant numbers of rotorcraft IFR flights are being performed at altitudes beneath communications and particularly surveillance coverages. IFR rotorcraft approaches and departures are also occurring at many heliports below current and planned coverages.

8.0 BENEFITS METHODOLOGY

Communications, surveillance, and air traffic control procedures can be improved in a number of locations to better enable rotorcraft to perform their mission. Section 8.1 describes the various benefits that rotorcraft operations would accrue from making seven different types of improvements. Section 8.2 provides an overview of the generalized benefit/cost methodology and section 8.3 details the procedures for computing the life cycle benefits and costs. This study concentrates on areas of greatest benefits. Other minor benefits may be important in some areas and should also be considered in the local area analysis.

8.1 BENEFITS OVERVIEW

8.1.1 Weather Regimes

The benefits realized by making specific improvements to the National Airspace System are dependent on the flight rules (IFR, VFR or SVFR) being followed by the rotorcraft and the frequency of low ceilings or poor visibility. The weather conditions and their effect on operations have been categorized based on three sources: the regulations in 14 CFR Part 91, General Operating and Flight Regulations; the recommended VFR weather minimums presented in FAA Advisory Circular 135-14A, Emergency Medical Services/Helicopter (EMS/H); and a review of weather minimums for a number of existing instrument approaches. An overview of the weather categories and the effect of weather on operations is presented in the first column of table 5; Benefits Overview.

The first source, the regulations in 14 CFR Part 91.105 identify weather below 1,000 feet or 3 miles as the conditions for which VFR operations are no longer permitted in a control zone. This weather criteria is expected to remain in effect for all control zones; no amendments are anticipated. It is also expected that the regulations prohibiting SVFR operations by fixed-wing aircraft within certain control zones (14 CFR Part 93.113) will not be amended to include rotorcraft.

The second source, the recommended VFR weather minimums contained in AC 135-14A, was selected to represent median VFR operating minimums for all rotorcraft missions. This conclusion was based on discussions with rotorcraft operators and a review of 153 EMS operators' VFR minimums (shown in table 6) which revealed that the EMS operators are using VFR minimums very close to the minimums in AC-135-14A (shown in table 4 on page 33) (see also reference 45).

TABLE 5
BENEFITS OVERVIEW

WX REGIME	Scenario 1 **Provide Comunications**	Scenario 2 **Provide Surveillance**	Scenario 3 **Provide Instrument Approaches**	Scenario 4 **Provide Converging Approaches/Diverging Departures**	Scenario 5 **Reduce Separation Minimums/Develop Helo Intercept Points**	Scenario 6 **Provide Charted Helicopters Routes**	Scenario 7 **Provide Dedicated Helicopters ATC Position W/Discrete Frequency**
1000'/3 mi ≤ WX Rotorcraft Operate VFR	BENEFIT #1 Pilots can obtain clearance through controlled airspace resulting in shorter routes BENEFIT #2 Pilots can obtain clearance to land at destinations in controlled airspace	None calculated	None calculated	None calculated	None calculated	BENEFIT #12 Charted VFR routes can increase number of destinations BENEFIT #13 Pilots receive clearances faster which reduces delays	BENEFIT #15 Rotorcraft receive clearances faster with less frequency changes, reducing delays
1000/3 mi > WX Night Cross Country Flown IFR Operations are SVFR in Control Zone 800'/2 mi > WX Night Local Flown IFR 1000'/1 mi > WX Day Cross Country Flown IFR	BENEFIT #1 & 2 BENEFIT #3 Pilots can obtain IFR clearance while airborne BENEFIT #4 Communications between IFR rotorcraft and ATC enable reduced separation	BENEFIT #5 IFR rotorcraft get vectored to the final approach fix and receive priority handling on request BENEFIT #6 Radar separation of IFR rotorcraft reduces delays BENEFIT #7 Radar separation of SVFR rotorcraft reduces delays	BENEFIT #8 Rotorcraft can fly IFR to destination	BENEFIT #9 Rotary/fixed-wing flight operations can be conducted simultan-eously which reduces delays	BENEFIT #10 Rotary/fixed-wing aircraft incur less delay with a rotorcraft intercept point BENEFIT #11 Rotary/fixed-wing aircraft incur less delays with reduced separation	BENEFIT #12 & 13 BENEFIT #14 Low altitude IFR helicopter routes reduce delays/cancellations	
466/3/4 ≤ WX < 500/1 All Flights Flown IFR; Non-Precision Approaches Used 200/1/2/ ≤ WX < 466/3/4 All Operations Conducted IFR, Precision Approches Used	BENEFIT #3 & 4	BENEFIT #5 & 6				BENEFIT #14	

TABLE 6 AVERAGE EMS/H VFR WEATHER MINIMUMS

CONDITIONS:	NONMOUNTAINOUS CEILING (feet)	NONMOUNTAINOUS VISIBILITY (miles)	MOUNTAINOUS CEILING (feet)	MOUNTAINOUS VISIBILITY (miles)
Day/Local	579	1.4	918	2.7
Day/Cross-Country	790	2.1	962	2.8
Night/Local	921	2.7	1827	4.4
Night/Cross-Country	1242	3.5	1823	4.3

The final source was based on a review of weather minimums for nonprecision rotorcraft-only instrument approaches. Published nonprecision instrument approaches for use by both fixed-wing and rotary-wing aircraft typically have ceilings and visibility of 600 feet and 1 mile or higher. However, for rotorcraft-only nonprecision instrument approaches, protected airspace areas are smaller and visibility requirements are reduced, as specified in United States Standards for Terminal Instrument Procedures (TERPS). These reduced visibilities typically permit lower weather minimums. Rotorcraft nonprecision instrument approach minimums for onshore locations (table 7) show average minimums to be 466 feet and just under 3/4 mile. These values will be considered representative of an average rotorcraft nonprecision approach.

TABLE 7 ROTORCRAFT-ONLY NONPRECISION INSTRUMENT APPROACH MINIMUMS
CEILING

APPROACH TYPE	SAMPLE SIZE	AVERAGE HAT	MINIMUM HAT	MAXIMUM HAT
NDB/DME	1	348	-	-
VOR/DME	10	352	290	520
RNAV*	10	502	300	620
VOR/DME Arc	1	515	-	-
RNAV	9	560	411	768
	31 (total)	466 (weighted average)		

* Point-in-Space

Note: HAT is height above touchdown

VISIBILITY:
1/2 mile - 14 approaches
3/4 mile - 17 approaches

Source: Reference 41.

An underlying assumption necessary for the application of the benefit/cost methodology developed in this report is that rotorcraft will operate under the appropriate flight rules based solely on the weather conditions. Possible exceptions to this assumption may occur when the weather is below minimums for only a portion of the flight. Rotorcraft would be required to fly IFR or VFR-over-the-top although weather is above the categorized minimums at the destination or origin. However, typical rotorcraft missions are relatively short, so variations in weather during a flight should not introduce a significant error.

Based on the above criteria, six weather categories have been developed to identify the flight rules rotorcraft follow. The first category is defined by AC 135-14A as weather of 1,000 feet and 3 miles or better. During these conditions, all rotorcraft operations are assumed to be conducted VFR. When the weather drops below either 1,000 feet or 3 miles, it is recommended that night cross-country flights be flown IFR.*

The next break point is at weather conditions below 1,000 feet or 3 miles. VFR flights are no longer permitted in a control zone, so flights must be conducted either IFR or SVFR. SVFR separations place added responsibilities on air traffic controllers, and improved communications, surveillance, or ATC procedures can enable rotorcraft flights to be more direct.

When weather is below 800 feet or 2 miles, night-local flights are flown IFR. Weather below 1,000 feet or 1 mile results in day-cross-country flights being flown IFR. The final two break points identify rotorcraft-only nonprecision instrument approach minimums and precision instrument approach minimums.

8.1.2 Scenario 1: Communications

Establishing a communications capability between pilots and controllers in gaps where communications is unavailable can provide four benefits.

8.1.2.1 Benefit #1 - Reduce Flight Time

Two-way communications are necessary for pilots to request and receive a clearance to fly through some controlled airspace when operating VFR. Airspace with such a requirement include control zones, terminal control areas (TCA), airport radar service areas (ARSA), and terminal radar service areas (TRSA). Receiving an appropriate clearance to fly through controlled airspace eliminates the requirement to circumnavigate the controlled airspace and a flight time savings may be realized.

*Note: Each EMS operator is responsible for determining the area around the dispatch locations that constitutes the local area. In general, this distance is approximately 25 nautical miles. Flights beyond a radius of 25 miles are assumed to be cross-country flights.

Typical VFR clearances permit nearly direct routing through controlled airspace (either by a clearance to continue as requested or by permitting overflight of the runway). In general, SVFR clearances (required only for control zones when weather is below either 1,000 feet or 3 miles) require radar surveillance or the absence of other IFR traffic in the vicinity of the airfield in addition to communications. Therefore, SVFR clearances at busy airfields require both communications and radar. At small airfields with relatively little IFR traffic, SVFR clearances require only communications.

For rotorcraft to maximize this benefit, effective en route communications coverage must extend down to 700 feet AGL. This communications coverage altitude would allow pilots to operate at an 800 foot ceiling with a 100 foot buffer area. Communications coverage at this altitude needs to extend 3 nautical miles beyond controlled airspace, as this distance gives the pilot 1.5 minutes to transmit a request and receive a clearance before entering controlled airspace, based on an airspeed of 120 knots.

An example of how a lack of communications can increase the flight distance and time of a flight is shown in figure 27. This figure represents the controlled airspace around Washington Dulles International Airport and a rotorcraft pilot desiring to fly from Leesburg to the location that is marked Hospital. If the ceiling were 1,500 feet and the visibility 3 miles or better, ATC would permit a relatively direct route through the controlled airspace. In this case, the route would be as depicted on the published helicopter route. Flying the helicopter route equates to a distance of 22 nm (11 minutes at 120 knots). Without communications, the only choice available to the pilot is to fly outside of controlled airspace. This circuitous route equates to a distance of 28 miles (14 minutes), resulting in a 3-minute time penalty to both the operator and passenger(s).

A number of locations have overlapping controlled airspace to the ground, such as the combined airspace over Washington National Airport and Andrews Air Force Base. Inadequate low altitude communications in this situation could increase the flight time by as much as 10 minutes. Because of this, each site must be analyzed individually to determine the effect of inadequate communications on flight operations. However, the more active controlled airspaces typically have communications coverage down to at least 700 feet AGL; therefore, pilots can request the necessary clearance to enter controlled airspace. At the more active terminal areas where communications are not adequate at low altitude, typically the cause has been masking by high terrain or tall buildings. In this case, the same obstructions may prevent rotorcraft from entering the controlled airspace from that location in either low ceilings or poor visibilities. Often, therefore, no operational capability is lost because of the low altitude coverage gaps.

The communications facilities necessary for pilots to request an appropriate clearance at low altitudes may be unavailable in less busy control zones. Therefore, pilots would have to circumnavigate the control zone. A worst case scenario would require a pilot to fly from just beyond one side of the control zone to just beyond the other side of the control zone. The

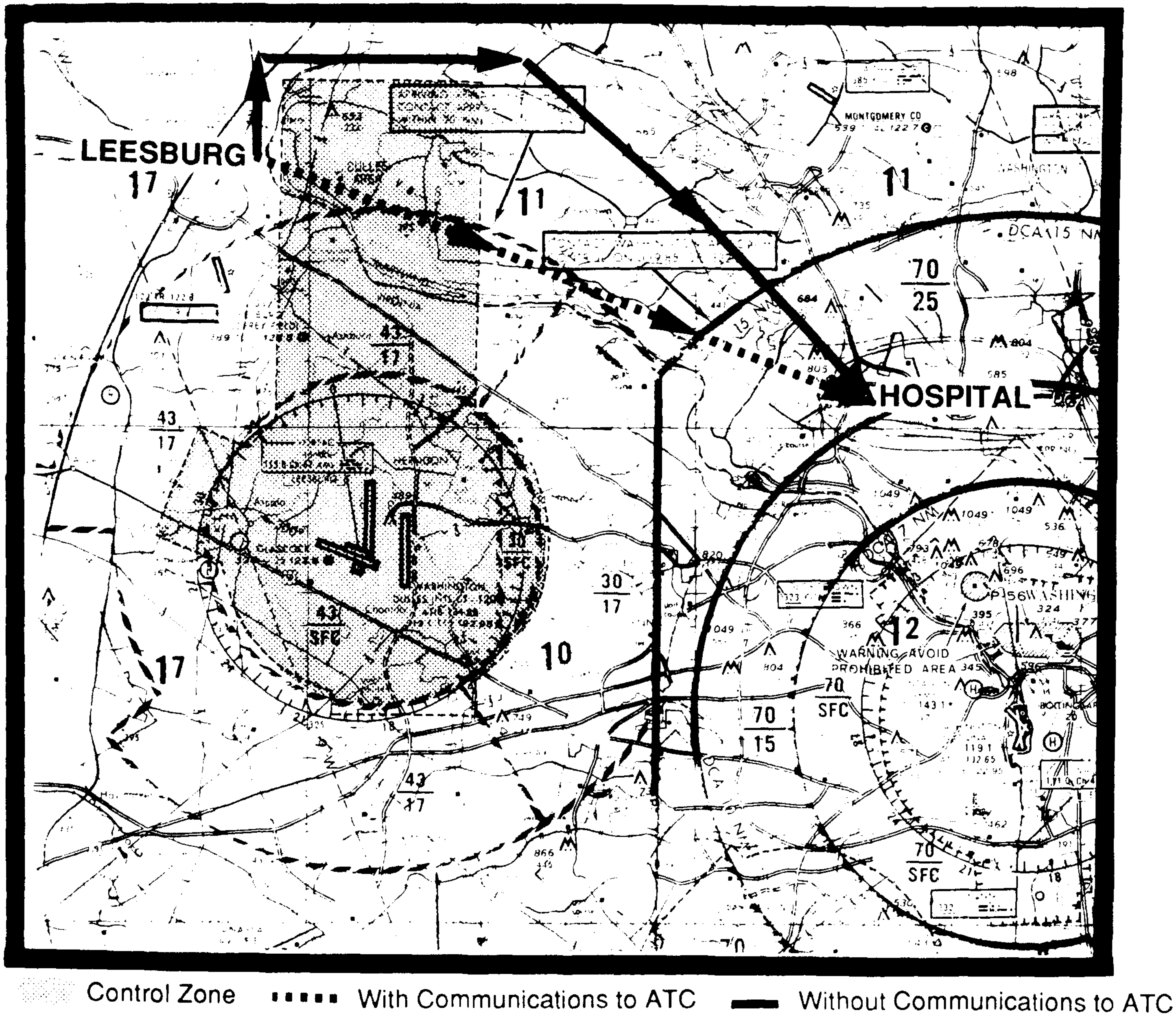


FIGURE 27 COMMUNICATIONS ENABLED FLIGHT ROUTE

difference in times between flying direct or circuitously is approximately 3.3 minutes. The monetary value of this benefit is not calculated in the recommended benefit/cost methodology because the small time intervals saved are of limited economic significance.

8.1.2.2 Benefit #2 - Land at More Destinations

Similar to benefit #1, communications are necessary for VFR rotorcraft pilots to enter and land at destinations within controlled airspace. Not being able to reach a destination within a control zone might lead to the cancellation of the flight. However, letters of agreement between local operators and the appropriate control facilities can be employed in many of these circumstances to waive specific communications requirements. Another option is to file an IFR flight plan if the destination is the airport. Also, in some cases, an instrument approach can be flown to the airport, followed by continued VFR flight to the rotorcraft destination after visual contact is made. Since there are a number of operational alternatives to achieve this benefit, it is not included in the recommended benefit/cost methodology.

8.1.2.3 Benefit #3 - Obtain IFR Clearances While Airborne

When the ceiling or visibility fall below VFR operational minimums after a pilot is airborne, an IFR clearance must be issued for the pilot to legally continue the mission as planned. If communications with approach/departure control or a flight service station are not possible, the pilot must abort the planned mission and land at an alternate destination or modify the flight plan to remain in VMC. Situations may also arise where a pilot must depart from a remote site that prevents an IFR flight plan from being filed while on the ground. To safely and legally operate, a flight plan must be filed shortly after departure while maintaining VMC. Communications coverage down to as low as 400 feet would be necessary to satisfy this requirement.

Pilots occasionally abort VFR missions due to deteriorating weather; however, few helicopter pilots seem to elect the IFR option as a means to complete a flight. The most common explanation is that they would not have attempted to fly the mission VFR in the first place if they could have received an IFR clearance to their destination. The reasons given for the inability to file an IFR flight plan were either due to the lack of an adequate instrument approach or the inability to operate IFR (due to an uncertificated IFR aircraft or a non-rated pilot). This explanation, combined with inadequate data to describe statistically deteriorating weather, makes computations to substantiate this benefit difficult to support. Therefore, it will not be included in the benefit/cost methodology.

A number of rotorcraft collisions with terrain or obstacles due to inadvertent entry into instrument meteorological conditions might have been averted if low altitude communications had permitted pilots to receive an IFR clearance. This problem is particularly appropriate to rotorcraft, since rotary-wing VFR operators' minimums are lower than fixed-wing operators' minimums. These minimums might allow operations below communications

altitudes, with the lower visibilities making inadvertent entry into instrument meteorological conditions far more likely. Often, pilots do not have the option of landing due to terrain considerations and, likewise, are not able to return to VMC.

A review of civilian helicopter mishaps due to inadvertent entry into instrument meteorological conditions from 1984 through 1987 was performed. During these 4 years, 40 such mishaps resulted in rotorcraft colliding with terrain or obstructions. A review of the mishaps to determine how many would have elected to obtain an IFR clearance if it were available was inconclusive; however, the percentage probably would not have exceeded 10 percent or an average of about one accident/year. In most cases, the rotorcraft crashed while the pilots were attempting to reverse course. This type of accident would not have been averted by filing IFR while airborne.

For rotorcraft and crews that are certificated to fly IFR, it is believed that there is a safety benefit related to the ability to file IFR when inadvertent IMC is encountered. Because is was not possible to quantify the number of averted accidents, this benefit was not included in the benefit/cost methodology.

8.1.2.4 Benefit #4 - Reduced Separation Enabled by Air/Ground Communication

Airspace capacity significantly increases when IFR aircraft can maintain continuous, direct communications with air traffic control. This increased capacity results in improved operational efficiency through more direct routing, less holding, and reduced delays in receiving clearances.

At locations where rotorcraft origins, destinations, and routes of flight are the same as or similar to fixed-wing aircraft, few communications deficiencies have been identified. In terminal areas shared by both fixed-wing and rotary-wing aircraft with moderate or higher activity levels, communications are generally adequate at all IFR altitudes. For the en route segment, some routes lack communications at low altitudes; however, rotorcraft can often be taken to a higher altitude without an operational penalty. En route separation requirements seldom force delays, even in the heavily trafficked areas of the Northeast.

Operations at Remote Airports/Heliports - However, rotorcraft operate IFR at a number of locations where poor low altitude communications cause operational problems. The solutions to these problems and the resultant benefits are dependent on whether rotorcraft are performing an instrument departure/approach or are en route. For the more remote terminal areas, specifically heliports located in areas without low altitude communications, operational problems include delays during approaches, departures, and issuance of departure clearances. Approach and departure delays result from the FAA air traffic controller's inability to apply appropriate separation standards. As a result, one ongoing IFR aircraft operation excludes all other operations to the same area until the pilot of the first aircraft can cancel the IFR flight plan via a phone call or perform a missed approach and climb to an altitude at which a position report can be radioed.

Pilots should file IFR flight plans at least 30 minutes prior to estimated time of departure to preclude possible delay in receiving a departure clearance. For most IFR operations, this is not a problem. One notable exception is the EMS pilot who needs to depart immediately. Also, a typical departure clearance in the absence of low altitude communications with approach/departure control includes a clearance takeoff window of 2 to 10 minutes. Being forced to depart under such stiff time constraints can be particularly troublesome to EMS and commuter operators who depend on timely mission completion for their success. With such small clearance windows, a small delay causing the window to be missed will result in another 30 minute delay while the flight plan is being refiled.

Operations for Offshore - At least one oil company has announced plans to develop oil and gas fields in the Gulf of Mexico more than 100 miles beyond the furthermost currently active oil rig off the Texas/Louisiana coast. Although a specific time frame was not addressed, it was indicated that this would be initiated within the next 5 to 10 years. Helicopter operators and air traffic personnel have accepted this plan and have expressed a need for additional capability to support the operation. In addition, a budgetary request has been initiated within the FAA's Southwest Region for additional RCAG facilities to prepare for such an eventuality.

The use of high frequency (HF) communications to support rotorcraft operations in the Gulf of Mexico is not considered a feasible solution by the Southwest Region. Appropriate air traffic control facilities in the area currently lack an HF communications capability and installing RCAG facilities is considered more cost effective. Rotorcraft would incur operational penalties as HF communications equipment is both bulky and heavy. In addition, the lengthy delays and poor voice communication qualities of HF make it unacceptable for use in air traffic control when smaller aircraft separations are desired.

Without the additional communications, rotorcraft operators flying far offshore could come in conflict with 14 CFR 135.165(b) which states: "No person may operate an aircraft...under IFR or in extended over-water operations unless it has at least the following communications and navigation equipment appropriate to the facilities to be used and which are capable of transmitting to, and receiving from, any place on the route, at least one ground facility:..."

It is also believed that virtually all operators would elect to fly to and from these rigs under IFR. At this distance from shore, ICAO separation standards, including 120-mile wide airways, would take precedence over domestic separation standards currently in use north of latitude 28° 15′ N. This could impose unrealistic IFR delays unless actions are taken to provide domestic aircraft separations, and dependable communications, navigation, and surveillance systems. Since actions have been initiated within the FAA's Southwest Region to address these potential difficulties, monetary benefits for far-offshore operations will not be addressed further in this report.

8.1.3 Scenario #2: Surveillance

Providing surveillance coverage in an area where it was previously lacking results in three benefits to rotorcraft operations. For these improvements to be realized, communications coverage must already be adequate down to the same altitudes as the surveillance coverage. These benefits will be dependent on whether rotorcraft are operating VFR/SVFR or IFR.

8.1.3.1 Benefit #5 - Surveillance Permits Aircraft to be Vectored and Receive Priority Handling

Radar surveillance permits air traffic controllers to vector IFR aircraft to the instrument approach intercept point. Radar vectoring in most cases eliminates the requirement for an aircraft to fly the procedure turn and reduces flight time by 5 to 7 minutes.

Radar surveillance of IFR aircraft also permits air traffic control to deliver priority handling to aircraft in an emergency situation. For most aircraft, priority handling will only be given if the aircraft is experiencing an in-flight emergency and must land as soon as possible. At air traffic control's discretion, priority handling can be extended to the EMS rotorcraft operation with a patient aboard who requires immediate medical attention. Priority handling would permit air traffic control to vector the EMS rotorcraft ahead of other aircraft and commence an approach sooner. This benefit would be rarely realized when rotorcraft commence approaches to destinations not shared by other aircraft, such as hospital helipads.

Upon the pilot's request, rotorcraft may also be vectored to inside the instrument approach intercept point but no closer than the final approach fix. Being vectored to the final approach fix can save as much as 5 minutes of flight time. However, since the economic value of this benefit is small and the number of times it would be used is difficult to quantify, it will not be included in the benefit/cost methodology.

8.1.3.2 Benefit #6 - Reduced Separation Enabled by Surveillance

In domestic airspace, IFR aircraft not under radar surveillance must be procedurally separated by either 10 minutes or 20 nautical miles. Radar surveillance by the appropriate ATC facility, on the other hand, permits IFR separation to be reduced to either 3 or 5 nautical miles. This reduced separation enables more efficient control of IFR rotorcraft by reducing delays when issuing clearances, reducing holding delays, and permitting more direct flight.

Based upon a telephone survey of operators, few operational problems due to lack of radar surveillance are encountered by rotorcraft while en route. In the more trafficked areas, surveillance is available at low IFR altitudes. For the less trafficked areas, there are two possibilities. Pilots can either fly at higher altitudes where radar surveillance is available or fly at lower altitudes where the airspace is uncongested and nonradar procedural separation may be adequate. A notable exception is in the Gulf of Mexico where surveillance capability would significantly reduce delays. At heliports with

IFR rotorcraft operations and no low altitude surveillance, procedural separation may result in delays. In most instances, only one instrument approach or departure may occur at any one time, and sequencing results in delays.

8.1.3.3 Benefit #7 - Reduce Delays Through Reduced SVFR Separation

SVFR operations require either 3 miles separation between IFR aircraft and SVFR aircraft or that the SVFR aircraft be 500 feet below the IFR aircraft. Lateral separation between IFR aircraft and SVFR rotorcraft or between two SVFR aircraft may be further reduced in some situations as specified in the Air Traffic Control Handbook (reference 37). These SVFR regulations afford rotorcraft considerably greater operational flexibility than fixed-wing aircraft, since rotorcraft can often fly into control zones without delays.

In control zones without low altitude surveillance, adequate separation is difficult to guarantee, and IFR aircraft operating to or from the airfield can result in delayed SVFR clearances being issued to rotorcraft. These delays would be virtually eliminated if low altitude surveillance coverage were improved. However, in the survey of the 50 locations no control zones without low altitude radar surveillance and with sufficient IFR traffic to cause delays to SVFR rotorcraft were identified. Therefore, because of a lack of operational requirements, the monetary value of this benefit is not included in the benefit/cost analysis.

8.1.4 Scenario 3: Nonprecision Approach

The emergence of new nonprecision approach capabilities, enabled by GPS and LORAN-C, may soon make instrument approaches possible at virtually any site. These approaches may provide an efficient and inexpensive new IFR capability to rotorcraft and it is believed this new capability will contribute to increased IFR rotorcraft flight.

8.1.4.1 Benefit #8 - Rotorcraft Can Fly IFR To Their Destinations

It will be necessary to develop nonprecision approaches in order to enable rotorcraft to fly IFR to their destinations. This will be particularly beneficial to the EMS mission where the lack of nonprecision approaches to hospital helipads is a critical constraint. At some locations, this benefit may be partially offset when aircraft fly an instrument approach to a nearby airport and proceed VFR to their destination.

8.1.5 Scenario 4: Point-In-Space Approaches

Frequent delays result from ATC's need to sequence rotorcraft and fixed-wing aircraft together in the terminal area when both are flying IFR. The difference in airspeeds between the two types of aircraft is a primary cause of delays to both rotorcraft and fixed-wing aircraft.

When rotorcraft are operating VFR, delays due to separation are rarely a problem, as rotorcraft routes of flight are separate from fixed-wing routes of flight. Similarly, at most airfields, VFR/SVFR rotorcraft approaches and

departures are used and provide adequate separation. Rotorcraft delays are also seldom encountered when operating SVFR.

8.1.5.1 Benefit #9 - Conduct Simultaneous Rotary-Wing and Fixed-Wing Operations in Terminal Areas

Current Air Traffic Control Handbook procedures (reference 37, paragraph 2-4) state "IFR traffic will be handled on a first come-first served basis." However, helicopter operators and many controllers have indicated that rotorcraft are delayed in certain situations when such an action can reduce the delay of a number of fixed-wing aircraft that carry significantly more passengers. In either scenario, rotorcraft and airplanes are experiencing unnecessary delays at high-density airports. If rotorcraft point-in-space approaches were developed at high-density airports, the time savings from having each rotorcraft fly the point-in-space approach rather than the nominal instrument approach procedures would result in a reduced delay of 3.49 minutes for subsequent fixed-wing aircraft that are separated by 3 miles. Table 8 demonstrates the improvement which results from a point-in-space approach. Without a rotorcraft point-in-space approach, aircraft would cross the runway threshold at the times shown. Incorporating a rotorcraft point-in-space approach removes rotorcraft from the fixed-wing traffic pattern. As a result, rotorcraft do not experience any delay and airplanes that would have followed the rotorcraft can be moved up a slot. Consequently, each following airplane at minimum separation would have its flight time reduced by 3.49 minutes. Supporting calculations are presented in appendix A.

TABLE 8 TIMES CROSSING THRESHOLD WITH AND WITHOUT A POINT-IN-SPACE APPROACH (MINUTES)

	WITHOUT POINT-IN-SPACE APPROACH	WITH POINT-IN-SPACE APPROACH	TIME SAVINGS
Airplane #1	0	0	-
Airplane #2	1.44	1.44	-
Airplane #3	2.88	2.88	-
Rotorcraft	6.37	No Delay	Variable
Airplane #4	7.81	4.32	3.49
Airplane #5	9.25	5.76	3.49

The rotorcraft would also incur an operational benefit since point-in-space approaches eliminate the need for rotorcraft to be sequenced. The rotorcraft would save a minimum of 1.47 minutes for every aircraft it would normally be sequenced behind when flying the nominal instrument approach.

8.1.6 Scenario 5: Rotorcraft Intercept Point/Reduced Separation Minimums

A rotorcraft point-in-space approach may be unsuitable at some airports for geographic reasons. If a separate point-in-space approach is not feasible, two modifications to current approach procedures would result in significant time savings for all IFR traffic. The first modification is to develop a rotorcraft intercept point that is positioned inside the approach

gate. The second modification is to reduce the separation between a rotorcraft over the runway threshold and a trailing aircraft. Both changes can be implemented separately or simultaneously and could provide safe improvements to the existing procedures.

8.1.6.1 Benefit #10 - Reduce Delays by Developing a Rotorcraft Intercept Point

Rotorcraft instrument approach procedures can be modified to establish a rotorcraft intercept point located inside the approach gate and ideally at the final approach fix, as shown in figure 28. This change would permit air traffic control to vector rotorcraft to intercept the final approach course approximately 3 miles closer to the airport. Both the rotorcraft and the in-trail aircraft would cross the runway threshold sooner.

Paragraph 5-120 a.(2) of the Air Traffic Control Handbook (reference 37) currently permits aircraft to be vectored to the final approach fix if specifically requested by the pilot. When the relatively slower airspeeds and higher maneuverability of the rotorcraft are taken into account, it is logical that rotorcraft could safely fly an approach after being vectored to the final approach fix. The Air Traffic Control Handbook could be revised as shown below:

CURRENT	ADD
Paragraph 5-120 a(2) ...2) If specifically requested by the pilot, aircraft may be vectored to intercept the final approach course inside the gate but no closer than the final approach fix.	...(3) Rotorcraft may be vectored to intercept the final approach course inside the gate but no closer than the final approach fix with pilot concurrence.

The first two columns in table 9 demonstrate the times aircraft would cross the threshold with and without a rotorcraft intercept point located at the final approach fix. At 3 miles separation, rotorcraft and subsequent in-trail airplanes would incur a reduced delay of 0.56 minutes (34 seconds). Supporting calculations for the threshold crossing times are presented in appendix A.

TABLE 9 TIMES CROSSING THRESHOLD WITH AND WITHOUT PROCEDURAL CHANGES*

	CURRENT PROCEDURES	WITH ROTORCRAFT INTERCEPT POINT	WITH 2 1/2 MILES SEPARATION	WITH BOTH CHANGES
Airplane #1	0 min	0 min	0 min	0 min
Airplane #2	1.44	1.44	1.44	1.44
Airplane #3	2.88	2.88	2.88	2.88
Rotorcraft	6.37	5.81/0.56	6.37/0.00	5.81/0.56
Airplane #4	7.81	7.25/0.56	7.57/0.24	7.01/0.80

/ = Time saving relative to current procedure

*See appendix A, Computation of Timesaving for Procedural Changes.

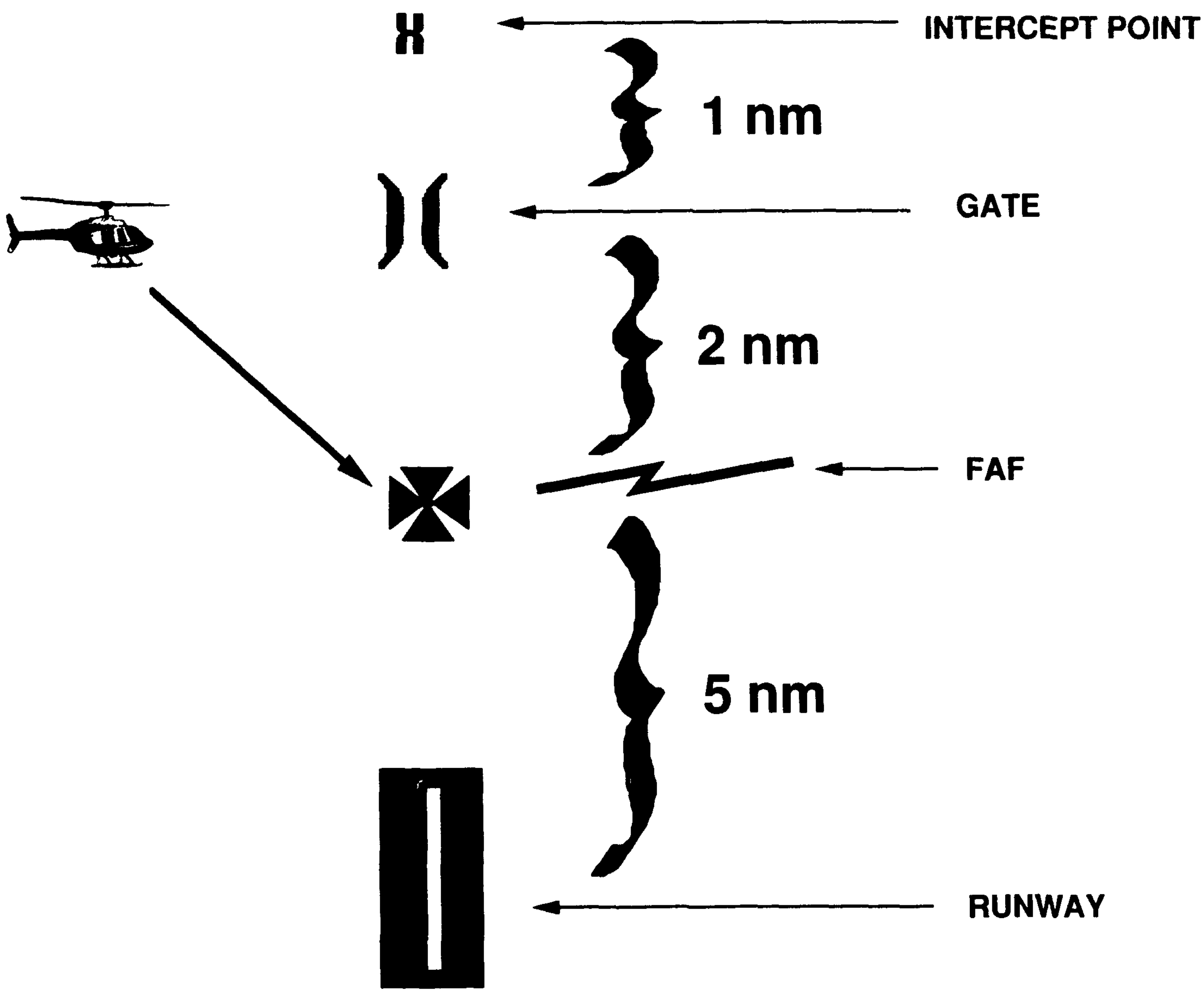


FIGURE 28 MODIFIED HELICOPTER APPROACH PROCEDURES

8.1.6.2 Benefit #11 - Decrease Delays by Reducing Separation Requirements

FAA Handbooks 7110.65F (paragraph 5-72d), "Air Traffic Control," and 7210.3I "Facility Operation and Administration" (paragraph 1236), do allow for reducing in-trail separation to 2.5 miles inside the final approach fix as long as certain safety requirements are met. The main requirements are a runway occupancy time of less than 50 seconds, runway turnoff points that are visible from the tower, and the leading aircraft's weight class being the same as or less than the trailing aircraft. These requirements would be met by rotorcraft as a typical rotorcraft instrument approach is terminated with the rotorcraft performing a low approach to the runway threshold followed by a hover taxi on to the helipad.

The third column in table 9 shows that using 2.5 miles separation would result in a time savings of 0.24 minutes for an in-trail aircraft. The fourth column shows a combined time savings of 0.80 minutes could be achieved if both changes were implemented. Saving 0.80 minutes can be a significant benefit when it affects a number of transport aircraft; furthermore, the costs of implementing these changes are negligible as they involve only procedural and training changes.

8.1.7 Scenario 6: Charted Helicopter Routes

Helicopter routes have been developed for both VFR and IFR operations. VFR helicopter routes have been published for New York, Washington D.C., Chicago, Los Angeles, and Boston. In these areas, operators and controllers praise their effectiveness. The same system of publicly charted helicopter routes could be developed for other areas where helicopter operators experience delays due to an inadequate helicopter route structure.

Change Three to the FAA Facility Operation and Administration Handbook 7210.3I provides instruction on the Helicopter Route Chart Program. The policy section states, "The Helicopter Route Chart Program has been established to enhance helicopter access into, egress from, and operation within high density traffic areas by establishing and charting discrete and/or common use helicopter routes, operating zones, and, where necessary, radio frequencies. The program has been designed to improve operational safety in areas where significant helicopter operations occur, and to establish a systematic process for chart development, modification, and acquisition."

The route section of Handbook 7210.3I states: "The routes that comprise a helicopter route chart should avoid the flow of IFR traffic and will normally be derived from existing FAA-operator letters of agreement. However, these routes may be expanded to permit transitions to, from, and between designated IFR routes and operational heliports/helistops, or to enable operators to circumnavigate designated operating areas when required."

Technically, helicopter route charts are for VFR use. However, the route charts can be used to provide SVFR clearances when approved by air traffic facility managers and the existing routes charts have been so approved. Benefits will therefore be computed in the benefit/cost analyses assuming rotorcraft can use these charts to operate SVFR in a control zone.

8.1.7.1 Benefit #12 - Operate at New Destinations

Helicopter operators are currently prevented from flying to many profitable destinations within controlled airspace and congested areas. They are subject to these limitations due to their interference with fixed-wing traffic flow, public protests concerning helicopter noise, and the public's perception of danger from helicopters flying nearby. In many areas, letters of agreement between local operators and ATC partially alleviate this problem. These letters of agreement benefit local operators but do little for itinerant operators.

Published helicopter route charts, however, provide itinerants with equal access to these routes. Local operators can also benefit. With published routes, they are no longer limited by letters of agreement which state that they must fly only specific routes. Published routes also alleviate public concern, since the routes are public information and can be specifically designed to ensure rotorcraft avoid noise sensitive areas and provide proper safety to the community. However, since an available destination can be currently used by operators with a letter of agreement, a monetary value for this benefit will not be computed.

8.1.7.2 Benefit #13 - Receive Clearances Faster

Reducing the number of letters of agreement and standardizing routes and procedures reduces both pilot and controller workloads. Standardization requires controllers to learn only one system instead of being current on all letters of agreement. The result is that clearances are issued faster and more precisely. This benefit is mainly qualitative and would result in only minor time savings. Therefore, a monetary value for this benefit will not be computed.

8.1.7.3 Benefit #14 - Reduce Delays/Cancellations with Low Altitude IFR Helicopter Routes

The wisdom of developing an IFR route system for the exclusive use of rotorcraft operations is an on-going debate in the aviation community. The intended benefits of such a system are to minimize the impact of fixed-wing traffic on rotorcraft operations and to enable more direct low-altitude IFR rotorcraft flight. Many rotorcraft proponents contend the rotorcraft's slower en route airspeed, higher variable operating costs, and shorter flight distances necessitate this special consideration. However, a comparison of the Northeast Corridor to the VOR Federal airways and the current limited use of the Northeast Corridor indicate the benefits derived from such a system are too small to warrant expansion of this system into other regions of the country. A benefit/cost analysis will therefore not be performed on an exclusive rotorcraft IFR route system.

The Northeast Corridor has been in existence for over 15 years and was designed as a pilot project to demonstrate the feasibility of such a system to support IFR rotorcraft operations in high density traffic areas. It connects Washington, D.C., New York, NY, and Boston (and sites in between) and is the only rotorcraft IFR route system in existence except for the Gulf of Mexico.

It therefore provides excellent insight into the capability of a rotorcraft-only IFR route system to satisfy user requirements.

The Northeast Corridor consists of two corridors; one supports northbound operations and the other southbound. It is considered a dynamic route structure with changes to be made as required and consists of 4 mile wide RNAV routes as compared to low-altitude VOR Federal airways which are 8 miles wide. This reduction in width is enabled by using closely spaced RNAV waypoints to define the airways. The reduced airway width is considered essential to minimize the interference to the existing low altitude airway system. Despite the specific goal of satisfying rotorcraft operational requirements, the Northeast Corridor is infrequently used. While some pilots use it, others have stated the routes are too far away from their origin or destination to be useful, access/egress is difficult, and the VOR Federal airways are adequate for their need. In some cases, helicopter operators and air traffic controllers were not even aware such a system existed.

The extent of interference from fixed-wing en route traffic also is questionable. Rotorcraft en route airspeeds are between approximately 90 and 150 knots which is not significantly slower than many airplanes that operate at low altitudes. The many IFR altitudes also eliminates bottlenecking problems in en route airspace and enables air traffic control to permit aircraft to cross and overtake without causing delays.

In a few terminal areas and adjacent airspaces, the VOR Federal airways are restricted from use by both fixed-wing and rotary-wing aircraft. One such example is the airspace to the northeast of LaGuardia and John F. Kennedy International Airports. Rotorcraft pilots flying in this area are frequently frustrated in their attempts to fly direct in the northeast/southeast directions. Instead of flying the Federal airways as filed, air traffic control reroutes them to the airspace over Long Island where they are integrated into the more congested traffic flows. For example, flying as filed from Hartford, CT to an initial approach fix at LaGuardia International Airport would take 40 minutes while the rerouted flight is 55 minutes. For operators, with approximately an 1.5 hours of usable fuel aboard and alternate airport requirements, the additional 15 minutes can prevent an IFR flight. If the flight is performed, the extra 15 minutes results in higher operational costs.

A number of rotorcraft pilots operating in this area find the rerouting costly, unnecessary and unacceptable. They are actively pursuing the development of an additional route to the Northeast Corridor that will permit them to fly relatively direct between origin and destination. However, from the air traffic controller's point of view, there is no distinction between a rotorcraft flying the VOR Federal airways or the Northeast Corridor. The problem will remain the same; how to safely and efficiently integrate them into the traffic flow in the vicinity of high traffic airports. The answer, independent of which airway system is used, is to develop rotorcraft standard terminal arrivals (STARs), rotorcraft point-in-space instrument approaches and rotorcraft standard instrument departures (SIDs) that fully utilize the rotorcraft's capabilities and the available airspace.

Because the problem is in the vicinity of high traffic airports, effectively using the VOR Federal airways in conjunction with tower en route control (TEC) still remains a viable option. The VOR Federal airways usually provides excellent flexibility and relatively direct routing. TEC also affords excellent communications and surveillance coverage down to the minimum en route altitude and/or minimum obstruction clearance altitude in virtually all high aircraft traffic areas. Remedying the VOR Federal airways to better support rotorcraft operations provides the most viable and economical solution and should be pursued.

8.1.8 Scenario 7: Dedicated Helicopter ATC Position With Discrete Frequency

A number of major terminal areas, including Boston Logan International, Washington National, and Los Angeles International Airports, currently have dedicated helicopter ATC positions with discrete frequencies. Most of these positions are manned only during periods of heavy traffic.

A potential safety improvement would be incurred by helicopters operating at low altitudes if they could use a discrete frequency. When pilots are able to listen to other pilots state their position, altitude, direction of flight, and intentions, they become more aware of other aircraft in the vicinity. Similarly, when listening to controllers issue clearances and advisories to like operations, pilots can better anticipate the clearances they will receive. This monitoring ability is an important safety factor but is not easily quantified, therefore the monetary benefit of this capability will not be computed.

8.1.8.1 Benefit #15 - Receive Clearances Faster

Having discrete frequencies results in less frequency changes for pilots. Frequency changes and delays receiving clearances from various controller positions were mentioned by pilots as causes of significant delay. Helicopter pilots operating at New York LaGuardia, for example, reported the need to contact four different controllers: clearance delivery, ground, local, and departure, even when flying only a few miles. Since rotorcraft flight paths are different from fixed-wing paths in most weather conditions, one controller could effectively handle all helicopters and eliminate most frequency changes.

Other controllers' workload would be lessened if one controller's primary duty was helicopter operations. The helicopter controller's increased awareness of rotorcraft operations would result in faster handling and issuance of clearances for helicopters. To implement a designated helicopter controller position at most busy terminal areas would require extra controllers during busy hours and, in some cases, installation of additional air traffic control equipment such as a controller workstation.

8.1.9 Summary

All of the preceding improvements could enhance rotorcraft activities to some degree and 15 specific benefits were cited. Six of the benefits are (or in the future may become) significant and methodologies to compute these benefits were developed. The remaining benefits are considered relatively

minor and/or difficult to quantify. A summary of the benefits as they impact IFR and VFR rotorcraft flight are presented in tables 10 and 11.

8.2 BENEFIT/COST METHODOLOGY OVERVIEW

Air traffic demand determines nearly all requirements for air navigation facilities and air traffic control services. However, since the FAA must operate, maintain, and improve the air navigation system within defined budgetary limitations, it is not economically feasible to satisfy all operational requirements. Therefore, to properly justify implementing any of the benefits presented in section 8.1, a benefit/cost analysis is essential.

Generally, implementing a change is justified when the present value of the benefits over the life cycle of an improvement exceed the total present value of the life cycle costs for establishment and maintenance of the improvement. This benefit/cost concept can be expressed in equation form:

$$\text{Benefits/Costs} = \frac{PV(SI+DR+CR+CS+O)}{PV(\text{FAA Costs}+\text{Operator Costs})}$$

Where: PV = Present Value
SI = Safety Increase
CR = Cancellation Reductions
DR = Delay Reductions
CS = FAA Cost Savings
O = Other Benefits

Safety increases are defined in terms of reduced risk of death, personal injury or property damage resulting from air traffic accidents. Delay/cancellation reductions allow more operations to be completed in the same amount of time. Cost savings are any reductions in expenditures the government or private sector would incur. Such savings may be in the form of direct cost savings where actual dollar outlays are reduced, or they may be indirect cost savings where actual dollar outlays are not reduced but efficiency gains allow for more benefit to be derived from each dollar spent. The "other" category includes additional benefits that cannot be captured by the other categories.

FAA costs are divided into facility/equipment costs and operational/maintenance costs. Included in facility equipment costs are the purchase and installation of equipment for ground and airborne systems. These costs are considered as lump sum costs required at the present time. Operational and maintenance costs are annual costs required each year to keep the ground and avionics systems functional. Operator costs are any cash outlays the private sector would incur to take advantage of the benefit. These might include expenditures for new avionics systems or an operational performance penalty from carrying increased weight of additional systems.

Benefits and costs are typically summed and discounted over a 15-year life cycle at a 10 percent annual discount rate. Net discount factors are applied

TABLE 10 BENEFITS FOR IFR FLIGHT

BENEFIT NUMBER	COMPUTED BENEFITS	REMARKS
4	Communications enable reduced separation.	Terminal area savings computed.
6	Surveillance enables reduced separation.	En route for Gulf of Mexico and terminal area savings computed
8	Non-precision approaches enable IFR flight.	GPS or Loran-C based system.
9	Point-in-space approach reduces delays.	Improvements to high-activity airports computed.
10	Rotorcraft intercept point reduces delays.	Improvements to high-activity airports computed.
11	Decreased separation reduces delays.	Improvements to high-activity airports computed .
	NON-COMPUTED BENEFITS	
3	Communications enable obtaining IFR clearance while airborne.	Benefits are questionable.
5	Surveillance enables vectoring/priority handling.	Benefits are minor.
14	Low-altitude rotorcraft routes enable more direct flight.	Benefits are minor.

TABLE 11 BENEFITS FOR VFR FLIGHT

BENEFIT NUMBER	NON-COMPUTED BENEFITS	REMARKS
1	Communications enable flight through controlled airspace.	Timesavings are minor.
2	Communications enable operations at more sites.	Procedural options minimize benefit.
7	Surveillance enables reduced separation of SVFR rotorcraft.	Benefits are minor.
12	Charted VFR routes enable itinerant operations at additional sites.	Benefits are minor.
13	Charted VFR routes reduces flight time.	Benefits are minor.
15	ATC position for rotorcraft handling enhances safety/reduces delays.	Difficult to properly quantify.

to treat these annual costs on a present value basis. This procedure is consistent with guidelines published by the Office of Management and Budget.

The FAA has developed precise operational criteria for establishment and discontinuance of communication systems, surveillance systems, and certain types of nonprecision approaches. These criteria are necessarily generalized for all aviation users. Applicable communications and surveillance systems costs are presented in appendix B.

The rotorcraft economic costs associated with delays and disruption are based on FAA values and methodologies (reference 49). These values have been adjusted as necessary to more accurately reflect specific rotorcraft mission costs and 1990 dollars, and are presented in table 12. Variable operating costs were obtained directly from FAA values for turbine rotorcraft (reference 49) and include fuel, oil, and maintenance costs. For the air taxi and commuter missions, crew expenses are included in variable operating costs.

Each mission's number of passengers/occupants per sortie was developed independently. For the EMS mission, the rotorcraft typically contains one pilot, one flight nurse, one emergency medical technician during all flight time, and a patient half of the time (reference 50). The number of occupants aboard a rotorcraft for the offshore mission was based on the Helicopter Safety Advisory Council's yearly passenger and sortie counts for operations in the Gulf of Mexico. Air taxi seating capacities for various helicopters were taken directly from FAA values for turbine rotorcraft (reference 49). The business mission by definition has the pilot as the person to be transported and presumably an average of one additional passenger. The corporate/executive mission's number of occupants was also taken from the FAA's economic values (reference 49) for the average rotorcraft with seating capacities of 10 or more passengers.

The value of an hour of a passenger's time was taken directly from the FAA's recommended values for rotorcraft passengers (reference 49). Three values are recommended: $75 for business trips, $112.50 for nonbusiness trips, and an average value of $78.34. In table 12, these values are multiplied by a factor of 1.116 to escalate values to 1990 dollars.

Total delay costs per hour are based on the rotorcraft's variable operating costs and the number of passengers multiplied by the value of their time. These values are presented in column F of table 12 for each mission under consideration.

For disruption costs, the assumptions and resultant equation that best capture rotorcraft costs are based on the general aviation instrument approach and disruption scenario. Flight disruptions experienced by most rotorcraft operators due to unacceptable weather at the destination would result from the pilot electing one of three options depending on the circumstances: (1) circle the airport/heliport until conditions improve (delay); (2) fly to a nearby airport/heliport where conditions are better (divert); or (3) if weather conditions are forecast to remain unacceptable, to cancel at the departure

TABLE 12 ROTORCRAFT ECONOMIC COSTS (1990 DOLLARS)

A	B	C	D	E	F	G
MISSION	VARIABLE OPERATING COSTS PER HOUR (1)	AVERAGE NUMBER OF PASSENGER/ OCCUPANTS	VALUE OF OCCUPANTS TIME (1)	DIVERTED PASSENGER HANDLING EXPENSE (6)	TOTAL DELAY COSTS PER HOUR (7)	TOTAL COST PER DISRUPTION (8)
EMS	$155.30	3.50 (2)	$125.55	$78.06	$594.73	$804.71
OFFSHORE	155.30	4.50 (3)	83.70	78.06	531.95	702.83
AIR TAXI	217.80	3.30 (4)	87.43	78.06	506.32	559.32
BUSINESS	155.30	2.00 (5)	83.70	78.06	322.70	331.35
CORP/EXEC	155.30	3.30 (4)	83.70	78.06	431.51	524.52
COMMUTER	217.80	4.80 (4)	83.70	78.06	619.56	761.15

(1) From reference 49 in 1987 dollars, multiplied by 1.116 to escalate to 1990 dollars.
(2) From reference 50.
(3) From Helicopter Safety Advisory Council.
(4) From reference 49.
(5) Pilot plus one passenger.
(6) From reference 48, $68.00 in 1985 dollars, multiplied by 1.148 to escalate to 1990 dollars.
(7) Column B + (Column C) (Column D).
(8) (1.71 Column D + 0.07 Column E) Column C + 0.22 Column B (Eq 1).

point (cancel). A remaining option for some fixed-wing pilots not considered for rotorcraft pilots is on multi-legged flights to overfly the intermediate destination (overflight).

Weighing the possibility of these three scenarios is best accomplished by applying the FAA's general aviation flight disruption costs equation (reference 48). This equation was based on a sampling of aircraft operations to determine the type of disruption that occurred and the resultant costs. The results of the sample revealed ˆ percent of the disrupted flights were delayed, 55 percent were canceled, and 7 percent were diverted. A cost equation was then developed by the FAA for each of the scenarios:

Disruption	Cost Equation
0.38 Delays	(0.5 Vpt)n + 0.30 AOC
0.55 Cancellations	(2.5 Vpt)n
0.07 Diversions	(2.0 Vpt + Vdvt)n + 1.5 AOC
1.00	

Combining the weighted averages of these three equations yields the equation:

$$\text{Cost/Disruption} = (1.71\ \text{Vpt} + 0.07\ \text{Vdvt})n + 0.22\ \text{AOC} \qquad \text{(Eq 1)}$$

Where: Vpt = Hourly value of a passenger's time
Vdvt = Rotorcraft passenger handling expense for diverted passengers
n = Number of passengers/occupants
AOC = Rotorcraft variable operating costs per airborne hour
Costs per disruption are presented in column G of table 12 for each mission under consideration.

Safety benefits are quantified based on a Poisson distribution of aircraft activity in a terminal area. For relatively small activity counts at heliports and small airports, this safety benefit tends to be negligible and will therefore be omitted from the final calculations.

8.3 BENEFITS METHODOLOGY

This section describes the procedures for computing the life cycle benefit/cost ratios of improvements most likely to affect existing and future rotorcraft operations. For each of the improvements, the primary benefit has been computed and secondary benefits have been omitted. This technique provides a focus on the primary function of each of the improvements, captures the bulk of the total benefits, and simplifies the methodology. In order to capture the difference between en route operations and terminal area operations, some benefits will be separated into two parts: an "A" will be used for the terminal area benefit and a "B" will be used for the en route benefit.

8.3.1 Terminal Communications (Benefit 4T)

A remote communications facility (RCF) installed at or in the vicinity of a high activity heliport could reduce rotorcraft IFR operational delays by

reducing spacing requirements. Computing the life cycle benefit/cost ratio requires five assumptions be made:

(1) in the absence of adequate communications coverage, a heliport attendant will provide limited liaison between a rotorcraft pilot and air traffic control;

(2) a nonprecision approach with the appropriate weather reporting system is already in place;

(3) communications between air traffic control and a rotorcraft pilot in a non-radar environment would most frequently result in 10 miles spacing between aircraft;

(4) 30 percent of rotorcraft operations at high activity airports are performed during "busy hours;" and

(5) high IFR rotorcraft activity levels will be realized only when weather is below 800 feet and 1 mile but at or above site specific nonprecision instrument approach weather minimums (400 feet and 3/4 mile will be used if site specific instrument approach weather minimums are unattainable).

At a number of existing heliports where communications coverage does not exist below the missed approach altitude, a heliport attendant often telephones air traffic control and reports that the rotorcraft is in sight (the IFR flight plan may also be canceled). This procedure significantly reduces the amount of time before the next rotorcraft may be cleared for an IFR operation by allowing another rotorcraft to be cleared for an IFR approach while the rotorcraft at the heliport shuts down. It is assumed this procedure will be used at all high activity heliports.

The second assumption dismisses the benefits from future installations of precision approaches at heliports, as it is difficult to properly assess the suitability of a site for a precision approach and the resultant weather minimums. This assumption may result in future benefits being significantly underestimated if precision approaches are installed. To capture the additional benefits from lower weather minimums, only a minor change to the methodology presented below is necessary.

Communications without surveillance can lead to a variety of spacings between aircraft, depending on the operational environment and the air traffic control procedures being employed. For this study, 10 miles spacing will normally be assumed. Less than 10 miles is achievable using timed approaches if an air traffic control tower is located at the heliport, but this appears unlikely. More than 10 miles may also occur in the total absence of surveillance, but the majority of heliports are located in areas where surveillance coverage is present down to the range of 2,000 to 4,000 feet AGL. This level of coverage enables air traffic control to more efficiently control terminal operations, resulting in spacings of approximately 10 miles.

Rotorcraft activity levels at heliports fluctuate according to the time of day and whether or not it is a weekday. Rotorcraft flight operations are typically the highest on weekdays between approximately 7:00 and 9:00 a.m. and between 4:00 and 6:00 p.m. (references 57 and 58). This methodology will assume it is during high activity hours or "busy hours" that IFR operations will experience the greatest delays and that during non-busy hours, the delays will be relatively minor.

Operational analysis of the Wall Street Heliport and the Indianapolis Heliport (references 57 and 58) showed the number of operations as a function of the time of day. The Wall Street Heliport, which almost exclusively supports business operations, has 40 percent of all operations occurring during only 4 hours a day during nonholiday weekdays for a total of 1000 hours a year (4 busy hours/day * 250 workdays/year) = 1000 busy hours/year). The Indianapolis Heliport supports a variety of missions, and 30 percent of its operations also occur during only 4 hours a day during nonholiday weekdays. A review of scheduled commuter operations at Boston's Logan International Airport also shows that 31.4 percent of all operations occur during only 4 busy hours. Therefore, 30 percent of all rotorcraft operations will be conservatively chosen to represent the number of rotorcraft operations conducted during busy hours.

A sufficient number of rotorcraft must fly IFR for delays to occur in the terminal area; this will usually happen when weather requires local operators to fly IFR. The busiest hours occur during daylight, so the weather minimums selected for this scenario will be day, local, IFR conditions (ceilings and visibility below 800 feet and 1 mile but at or above site specific instrument approach weather minimums; 466 feet and 3/4 mile will be used if the instrument approach weather minimums are unavailable).

Based on these assumptions, five steps are required to compute the life cycle benefit/cost ratio of installing a remote communications facility:

1) determine the number of busy IFR hours at the heliport using the following equation:

   Busy IFR Hours/Year = (Busy Hours/Year)(% IFR Weather), (Eq 2);

2) identify the average number of rotorcraft IFR operations performed during a busy IFR hour using the following equation:

   Busy Rotorcraft IFR Operations/Year = (Rotorcraft IFR Operations/Year)(0.3), (Eq 3);

3) look-up the decrease in the total delay times in a table using the values from steps 1) and 2);

4) find the total annual costs savings from the delay reduction; and

5) compute and ratio the life cycle benefits and costs.

Step 1 - The number of busy IFR hours at a heliport will be determined by multiplying the number of busy hours (estimated above to be 1000 hours a year) by the percentage of time the weather is below 800 feet and 1 mile but at or above local nonprecision approach weather minimums (data taken from the FAA's airport specific file weather data base, reference 14). In the absence of site specific nonprecision approach minimums, an average value of 466 feet and 3/4 mile will be used.

Step 2 - The average number of rotorcraft IFR operations performed during a busy IFR hour must be determined by first identifying the number of IFR operations occurring annually. This annual operations data has been published by the FAA for only two heliports (references 57 and 58). For other heliports, the number of IFR operations and the types of missions flown must be estimated, based on discussions with rotorcraft operators and fixed-base operators. The forecast data presented in the preceding first interim report (reference 10) will also be used to adjust the estimates. Next, the number of annual IFR operations should be multiplied by the 30 percent ratio of busy-hour to normal-hour operations (from assumption four) to determine the number of annual busy IFR operations.

Step 3 - In order to determine the total amount of delay in minutes, table 13 must be entered with a value for the "Average Number of Busy IFR Operations Per Hour." This value is obtained by dividing (Busy Rotorcraft IFR Operations/Year), from equation 3, by (Busy IFR Hours/Year), from equation 2, to obtain the average number of busy IFR operations per hour. Entering the left column of table 13, the total amount of delay reduction per hour is obtained in minutes for either 10 miles or 15 miles spacing. Table 13 is based on a standard queuing equation and assumptions, as described in appendix C. The appropriate queuing equations (eq 4 and 5) may be applied in lieu of table 13 when the average number of busy IFR operations per hour is not an integer.

Most instrument approaches will have an initial approach fix at or below 4,000 feet AGL and 10 miles spacing is appropriate. At heliports where the initial approach fix is above 4,000 feet, 15 miles spacing is correct.

10 Mile Spacing (Use when initial approach fix is at or below 4,000 ft AGL.)

$$\text{Delay Reduction (min)} = 60*((\text{operations per hour}/6)^2/(1-(\text{operations per hour}/6)) - (\text{operations per hour}/18)^2/(1-(\text{operations per hour}/18))), \quad \text{(Eq 4)}$$

15 Mile Spacing (Use when initial approach fix is above 4,000 ft AGL.)

$$\text{Delay Reduction (min)} = 60*((\text{operations per hour}/6)^2/(1-(\text{operations per hour}/6)) - (\text{operations per hour}/12)^2/(1-(\text{operations per hour}/12))), \quad \text{(Eq 5)}$$

TABLE 13 DELAY REDUCTIONS PER BUSY HOUR BY ADDING COMMUNICATIONS

AVERAGE NUMBER OF BUSY IFR OPERATIONS PER HOUR	10 MILES SPACING (MINUTES)	15 MILES SPACING (MINUTES)
1	2	2
2	9	8
3	28	25
4	76	70
5	244	232
6	OC*	OC*

* Over Capacity - Theoretically an ultimate capacity of six operations per hour without ATC communications is achievable. In a realistic environment, operational inefficiencies, described by the queuing model, degrade the theoretical capacities.

At some IFR activity level, operations without communications have unacceptably high delays and rotorcraft operators will choose to disrupt flights (cancel or fly to an alternate destination) rather than incur excessive delays. Since operators' motivations are primarily financial, disruptions were selected to begin at the activity level at which delay costs exceed disruption costs. For purposes of assessing communications needs, total delay costs exceed disruption costs when more than 5.28 IFR operations per hour are performed. Therefore, when activity levels exceed this rate, 5.28 IFR operations will be considered delayed and the remainder will be considered disrupted.

Step 4 - The total annual cost savings from reduced delays is determined by multiplying the decrease in total delay times per busy IFR hour (step 3) by the number of busy IFR hours per year (step 1), resulting in the total annual hourly delay reduction:

Delay Reduction/Year = (Delay Reduction/Hour)(Busy IFR Hours/Year), (Eq 6)

This value should then be multiplied by a site specific weighted average of total delay costs presented in table 12:

Savings/Year = (Delay Reduction/Year)(Delay Costs), (Eq 7)

In a similar manner, the savings from reduced disruptions should be computed.

Step 5 - To perform the life cycle benefit/cost analysis, a 15-year life cycle is assumed and discounted at a rate of 10 percent with a mid-year convention. A terminal communications system (remote transmitter/receiver) would be the system most likely to be installed, as terminal IFR operations are most frequently provided by approach control. Total 15-year life cycle costs for this system are $431,181 (costs are presented in appendix B).

The total life cycle benefits of the delay reduction is the sum of the present value of annual delay reductions over a 15 year period. Savings from annual delay reductions will be computed individually when large increases in rotorcraft IFR activity are forecasted. For most sites, this report will compute the projected delays for each year using forecasts of increased IFR activity levels. Total life cycle benefits will be computed by discounting the cumulative benefits occurring each year by the appropriate adjusted discount rate using a midyear convention and then summing the discount annual benefits.

To standardize the methodology and simplify the computations, three benefits from installing a remote communications facility will not be computed. These are listed below:

1) Approximately 70 percent of the rotorcraft operations at high activity heliports occur during non-busy hours. Rotorcraft may still experience operational delays during these non-busy hours, but the delay reductions are expected to be a small percentage of the total annual delays and will be omitted from the calculations.

2) Expanding the communications coverage presumably would reduce the likelihood of a midair collision due to an increase in air traffic control services. Based on FAA accepted equations, this likelihood increases exponentially as the traffic congestion increases. Considering the relatively small number of IFR operations, the likelihood of reducing a midair collision is considered to be extremely small, and the benefits from increased safety are assumed to be negligible.

3) Lastly, most rotorcraft are used because they provide a convenient and efficient means of transportation. Reducing operational delays would enhance the rotorcraft operators' competitive posture and possible increase business. The resulting increase in business, while potentially significant, will not be estimated because it is very difficult to quantify.

An increase in low altitude communications services would not result in a noticeable improvement to any rotorcraft en route operations, either VFR or IFR with one exception. In the Gulf of Mexico, local pilots and air traffic controllers believe a need for communications will arise within the next 10 years in regions beyond 150 miles offshore. Specific outer regions as far as 200 miles offshore have already been identified for further oil exploration and drilling. Since this benefit is Gulf of Mexico specific, computations of the benefits from reduced delays are based on discussions with the air traffic controllers at Houston Center. This site specific analysis will be incorporated into the final report.

8.3.2 Terminal Surveillance (Benefit 6T)

Surveillance from a terminal radar enables 3 miles separation to be achieved when an aircraft is within 40 miles of the antenna. The reduction in

separation may result in reduced IFR operational delays at many high activity heliports where low altitude communications already exist.

Due to the high cost of a terminal radar system, it is unlikely that the benefits from operational delay reductions at any heliport would outweigh the high life cycle costs of the radar. However, under the new establishment criteria for terminal radar, an area ratio value may be computed by summing the benefit/cost ratios for each of the heliports/airports that would derive a benefit from improved surveillance. These benefit/cost ratios have already been computed for most airports having moderate activity or higher and are presented in "Investment Criteria for Airport Surveillance Radar (ASR/ATCRBS/ARTS)" (reference 47). Total benefits will be computed by summing the improved surveillance benefits at all sites.

Computing the benefits from improved terminal surveillance requires the application of the same procedures used to compute the terminal communications benefits in section 8.3.1. However, modifications are made to account for differences in aircraft separation between a radar and nonradar environment. Five steps are required to compute the life cycle benefit/cost ratio of installing a terminal radar:

1) determine the number of busy IFR hours at the heliport using the following equation:

   Busy IFR Hours/Year = (Busy Hours/Year)(% IFR Weather), (Eq 8);

2) identify the average number of rotorcraft IFR operations performed during a busy IFR hour using the following equation:

   Busy Rotorcraft IFR Operations/Year = (Rotorcraft IFR Operations/Year)(0.3), (Eq 9);

3) determine the decrease in the delays and disruptions between a radar and nonradar environment using the values from equations 8 and 9;

4) find the total annual costs savings from the reduction in delays and disruptions; and.

5) compute and ratio the life cycle benefits and costs.

<u>Step 1</u> - The number of busy IFR hours at a heliport will be determined by multiplying the number of busy hours (estimated above to be 1,000 hours a year) by the percentage of time the weather is below 800 feet and 1 mile but at or above local nonprecision approach weather minimums (data taken from the FAA's airport specific file weather data base, reference 14). In the absence of site specific nonprecision approach minimums, an average value of 466 feet and 3/4 mile is used.

<u>Step 2</u> - The average number of rotorcraft IFR operations performed during a busy IFR hour must be determined by first identifying the number of IFR operations occurring annually. This annual operations data has been published by the FAA for only two heliports (references 57 and 58). For other

heliports, the number of IFR operations and the types of missions flown must be estimated based on discussions with rotorcraft operators and fixed-base operators. The forecast data presented in the preceding first interim report (reference 10) is also used to adjust the estimates. Next, the number of annual IFR operations should be multiplied by the 30 percent ratio of busy-hour to normal-hour operations (from assumption four) to determine the number of annual busy IFR operations.

Step 3 - In order to determine the total amount of delay reduction in minutes, table 14 must be entered with a value for the "Average Number of Busy IFR Operations Per Hour." This value is obtained by dividing (Busy Rotorcraft IFR Operations/Year), from equation 9, by (Busy IFR Hours/Year), from equation 8, to obtain the average number of busy IFR operations per hour. Entering the left column of table 14, the total amount of delay reduction per hour is obtained in minutes for 10 miles spacing.

Table 14 is based on a standard queuing equation and assumptions, as described in appendix C. When the "Average Number of Busy IFR Operations Per Hour" is not an integer, the queuing equation (10) may be used in lieu of table 14.

Delay Reduction (minutes) = $60*((\text{Operations per Hour}/18)^2/(1-(\text{Operations per Hour}/18))-(\text{Operations per Hour}/30)^2/(1-(\text{Operations per Hour}/30)))$, (Eq 10)

TABLE 14 DELAY REDUCTION PER BUSY HOUR IN TERMINAL AREAS BY ADDING SURVEILLANCE

AVERAGE NUMBER OF BUSY IFR OPERATIONS PER HOUR	DELAY REDUCTION (MINUTES)*
1	0
2	1
3	1
4	3
5	4
6	7
7	11
8	16
9	22
10	32
11	45
12	64
13	93
14	139
15	220
16	390
17	919
17.23	1,239

* Improvement from 10 mile separation to 3 mile separation.

At some IFR activity level, delays become unacceptably high without surveillance and rotorcraft operators will choose to disrupt flights rather than incur excessive delays. Since operators' motivations are primarily financial, disruptions were selected to begin at the activity level at which delay costs exceed disruption costs. For purposes of assessing surveillance needs, delay costs exceed disruption costs when more than 17.23 IFR operations per hour are performed. Therefore, when activity levels exceed this rate, 17.23 IFR operations per hour will be considered delayed and the remainder will be considered disrupted.

Step 4 - The total annual cost savings from reduced delays is determined by multiplying the decrease in total delay times per busy IFR hour (step 3) by the number of busy IFR hours per year (step 1), resulting in the total annual hourly delay reduction:

Delay Reduction/Year = (Delay Reduction/Hour)(Busy IFR Hours/Year), (Eq 11)

This value should then be multiplied by a site specific weighted average of total delay costs presented in table 12:

Savings/Year = (Delay Reduction/Year)(Delay Costs), (Eq 12)

In a similar manner, the savings from reduced disruptions should be computed.

Step 5 - To perform the life cycle benefit/cost analysis, a 15-year life cycle is assumed and discounted at a rate of 10 percent with a mid-year convention. Total 15-year life cycle costs for an ASR-9 are $7.19 million in 1990 dollars (costs are presented in appendix B).

The total life cycle benefits of the delay reduction is the sum of the present value of annual delay reductions over a 15 year period. Savings from annual delay reductions are computed individually when large increases in rotorcraft IFR activity are forecasted. For most sites, this report will compute the projected delays for each year using forecasts of increased IFR activity levels. Total life cycle benefits will be computed by discounting the cumulative benefits occurring each year by the appropriate adjusted discount rate using a midyear convention and then summing the discount annual benefits.

To standardize the methodology and simplify the computations, three benefits from installing a terminal radar will not be computed. These are listed below:

1) Approximately 70 percent of the rotorcraft operations at high activity heliports occur during non-busy hours. Rotorcraft may still experience operational delays during these non-busy hours, but the delay reductions are expected to be a small percentage of the total annual delays and will be omitted from the calculations.

2) Expanding surveillance coverage presumably would reduce the likelihood of a midair collision due to an increase in air traffic control services. Based on FAA accepted equations, this likelihood increases

exponentially as the traffic congestion increases. Considering the relatively small number of IFR operations, the likelihood of reducing a midair collision is considered to be extremely small, and the benefits from increased safety are assumed to be negligible.

3) Lastly, most rotorcraft are used because they provide a convenient and efficient means of transportation. Reducing operational delays would enhance the rotorcraft operators' competitive posture and possible increase business. The resulting increase in business, while potentially significant, will not be estimated because it is very difficult to quantify.

As an example, the benefits from reducing delays and disruptions by introducing terminal surveillance to a heliport that exclusively supports commuter operations are computed. At this example heliport 2,000 instrument operations are performed per year and the airport specific file shows local weather is below company VFR operating minimums but above instrument approach minimums 4 percent of the time.

The first step is to compute the "Busy IFR Hours/Year". Using equation 8, 1000 Busy Hours/Year * 4 % IFR Weather = 40 Busy IFR Hours/Year. Step 2 determines the average number of rotorcraft IFR operations performed during a busy IFR hour. To perform step 2 use equation 9, (2,000 Rotorcraft IFR Operations/Year) * (.3 Ratio of Busy to Normal Rotorcraft Operations) = 600 Busy Rotorcraft IFR Operations per Year).

At this point, step 3 is performed. The "Average Number of Busy IFR Operations per Hour" is calculated by dividing "Busy Rotorcraft Operations per Year" by "Busy IFR Hours/Year." In this case, 600/40 equals "15 Average Number of Busy IFR Operations per Hour." From table 14 or from equation 10, the "Delay Reduction per Busy IFR Hour" from adding surveillance is 220 minutes.

For this example, commuter operations are projected to grow at 3.0 percent per year. Delay reduction for each year over a 15-year life cycle therefore must be computed. Once the "Average Number of Busy IFR Operations per Hour" exceeds 17.23, the remaining flights become disrupted. In this example, without radar surveillance, disruptions will begin to occur in 1997 and an average of 17.23 flights will incur a total delay per hour of 1,239 minutes and all additional flights will be disrupted.

To determine the annual cost savings as directed in step 4, multiply the delay reduction per hour by the number of busy IFR hours per year. For this heliport, (220 Minutes/Busy IFR Hour * 1 Hour/60 Minutes) * (40 Busy IFR Hours/Year) = 147 Hours Delay Reduction/Year. Next, annual costs savings need to be determined. The delay costs per hour for a commuter operation is $619.56; therefore, (147 Hours Delay Reduction/Year) * (619.56 Dollars)/ Hourly Delay Reduction = 90.9 thousand dollars savings/year.

In a similar manner, the yearly number of disrupted flights must be multiplied by their disruption value, when applicable. For each year, the benefits from reducing delays and disruptions must be computed and then

multiplied by the discount factor. For this sample heliport, total, discounted 15-year life cycle benefits would be nearly 3.0 million dollars.

The entire analysis is presented in table 15 in a spreadsheet format.

8.3.3 En Route Surveillance (Benefit 6E)

The lack of low altitude surveillance for en route flights does not constrain rotorcraft IFR operations in any area that has been investigated except for the Gulf of Mexico. In the Gulf of Mexico, air traffic controllers have agreed the average delay for an IFR operation is 30 to 45 minutes. This delay most frequently occurs in the issuance of a clearance prior to departure. In their opinion, this wait could be decreased to 15 minutes if LORAN Offshore Flight Following (LOFF) were implemented, or decreased to 5 minutes if three radars were strategically placed in the Gulf of Mexico. Air traffic controllers have also stated that many of the delays are caused by morning fog, and while the fog may eventually lift, the early morning delays create a ripple effect which operators continue to experience for the remainder of the day.

The following assumptions are made in developing this benefit equation:

1) the average offshore operator performs six sorties a day during daylight hours, Monday through Friday;

2) the number of offshore operations will increase as forecasted in figure 51 from the first interim report (reference 10) and future delays will be linearly related to this increase;

3) high IFR activity levels will occur when the weather requires day local operations to be performed IFR; and

4) 90 percent of the IFR-operated rotorcraft are flying on any given weekday.

The first assumption is based on data provided by the Helicopter Safety Advisory Conference (HSAC). This data shows that each operational rotorcraft averages six sorties per day with virtually all operations occurring Monday through Friday during daylight hours. Discussions with offshore rotorcraft operators in the Gulf of Mexico confirmed that virtually all rotorcraft operations occur Monday through Friday during daylight. Day local IFR weather minimums will therefore be applied.

The second assumption is that future delays will increase linearly as a function of projected offshore IFR operations. Currently, 115 IFR rotorcraft in the Gulf of Mexico experience an average delay of 37.5 minutes per IFR operation. For this analysis, the number of IFR rotorcraft will be assumed to increase at the same rate as forecasted for the entire offshore rotorcraft

TABLE 15 BENEFITS FOR ADDING RADAR SURVEILLANCE AT AN IFR HELIPORT

(Example Benefit Problem)

Mission: Helicopter Commuter	
Mission Growth Rate	3.00%
Percent IFR Weather	4.00%
Busy Hours/Year	1,000
Busy IFR Hours/Year	40
Percent Busy Hour Operations	30%
Delay Cost/Hour	$619.56
Cost/Disruption	$761.15

Cum Years	Year	Annual Instrument Operations	Annual Busy Hour Operations	Average IFR Busy Ops/Hour	Delay Reduction per IFR Hr (min)	Annual Delay Reduction (hours)	Annual Delay Cost Savings	Averted Disruptions per IFR Hour	Annual Averted Disruptions	Annual Disruption Cost Savings	Total Cost Savings (Benefits)	Discount Factor	Discounted Benefits	Cum Benefits (k$)
1	1992	2,000	600	15.0	220	147	$90,869	0.0	0	$0	$90,869	0.953	$86,640	$86.6
2	1993	2,060	618	15.5	279	186	$115,328	0.0	0	$0	$115,328	0.867	$99,965	$186.6
3	1994	2,122	637	15.9	371	248	$153,387	0.0	0	$0	$153,387	0.788	$120,867	$307.5
4	1995	2,185	656	16.4	521	347	$215,103	0.0	0	$0	$215,103	0.716	$154,089	$461.6
5	1996	2,251	675	16.9	800	534	$330,580	0.0	0	$0	$330,580	0.651	$215,283	$676.8
6	1997	2,319	696	17.4	1,239	826	$511,757	0.2	7	$5,176	$516,932	0.592	$306,037	$982.9
7	1998	2,388	716	17.9	1,239	826	$511,757	0.7	27	$20,399	$532,155	0.538	$286,409	$1,269.3
8	1999	2,460	738	18.5	1,239	826	$511,757	1.2	49	$37,144	$548,901	0.489	$268,565	$1,537.9
9	2000	2,534	760	19.0	1,239	826	$511,757	1.8	71	$53,889	$565,646	0.445	$251,598	$1,789.5
10	2001	2,610	783	19.6	1,239	826	$511,757	2.3	94	$71,396	$583,152	0.404	$235,804	$2,025.3
11	2002	2,688	806	20.2	1,239	826	$511,757	2.9	117	$88,902	$600,659	0.368	$220,803	$2,246.1
12	2003	2,768	831	20.8	1,239	826	$511,757	3.5	142	$107,931	$619,688	0.334	$207,089	$2,453.1
13	2004	2,852	855	21.4	1,239	826	$511,757	4.1	166	$126,199	$637,955	0.304	$193,812	$2,647.0
14	2005	2,937	881	22.0	1,239	826	$511,757	4.8	192	$145,989	$657,745	0.276	$181,659	$2,828.6
15	2006	3,025	908	22.7	1,239	826	$511,757	5.5	219	$166,540	$678,296	0.251	$170,304	$2,998.9

fleet (see figure 50 of the first interim report (reference 10)). Future delays per IFR rotorcraft will be projected using the following equation:

Delay/Sortie(Year N) = [37.5 Minutes/Sortie)] * [Number of IFR Rotorcraft (Year N)/(115 IFR Rotorcraft)], (Eq 11)

This equation should provide a slightly conservative estimate of the average delay each rotorcraft will experience as the number of IFR rotorcraft increases. Actual delays will tend to be underestimated if the number of IFR rotorcraft increases significantly. A sensitivity analysis will also be performed to reflect other possible average delays of 30 and 45 minutes without surveillance.

The final assumption relates the number of operational IFR rotorcraft to the number of IFR rotorcraft known to be based in the area. A 0.90 ratio will be used to correct for the number of rotorcraft that will typically be inoperative (approximately 10 percent) for maintenance reasons or pilot unavailability. For more information about operations in the Gulf of Mexico refer to section 3.3.

Three steps are required to compute the total life cycle savings:

1) determine the number of flights affected annually by IFR delays,

2) determine the annual cost savings from reduced delays resulting from 1) LOFF and 2) radar surveillance, and

3) compute and ratio the life cycle benefits and costs.

The number of annual flights affected will be determined by multiplying the number of operational IFR rotorcraft by six sorties per rotorcraft per day by the number of days the rotorcraft are operated IFR:

Sorties/Year = (0.9)(IFR Rotorcraft)(6 Sorties/Rotorcraft/Day)(IFR Days/Year), (Eq 12)

The 37.5 minutes of delay currently experienced per rotorcraft per IFR operation cannot be totally eliminated by either LOFF or ASR-9 installations. Therefore, equation 11 should be changed to reflect the amount of delay which will remain after the implementation of either form of surveillance in the Gulf. This is the necessary equation:

Delay Reduction/Sortie = (37.5-S) (Minutes/Rotorcraft/115 IFR Rotorcraft) (Number of IFR Rotorcraft), (Eq 13)

Where "S" equals the amount of delay which will remain after surveillance is implemented. Based on discussions with Gulf controllers, reasonable estimates are S = 5 minutes for ASR-9, S = 15 minutes for LOFF.

The annual cost savings from delay reduction can then be computed by applying the equation:

Savings/Year = (Sorties/Year)(Delay Reduction/Sortie)(Delay Costs), (Eq 14)
(Eq 12) (Eq 13) (table 12 column F)

Delay costs are taken from table 12 for the offshore mission. Annual delay reductions for each year in a 15-year life cycle will be computed and discounted to reflect total life cycle benefits. LOFF and radar life cycle costs are presented in appendix B.

8.3.4 Nonprecision Approaches (Benefit 8)

Two separate equations have been developed for the nonprecision approach benefit: one for all mission types except EMS, another for only the EMS mission. Rotorcraft missions other than EMS typically involve short distances, so when weather is forecast to be at or below VFR minimums at a destination heliport without a nonprecision approach, pilots usually opt to either cancel the flight, postpone the flight, or divert. A weighted average of these three options is the disruption costs (see equation 1).

The equation which will be used to calculate the nonprecision approach benefit is as follows:

Savings/Year = (Rotorcraft VFR Operations/Year)[(% IFR Weather)/(1-% IFR Weather)](% IFR Certified Aircraft)(Disruption Costs), (Eq 15)

The value for disruption costs is taken from table 12, column G. Life cycle benefits will be computed by summing the discounted annual benefits per year. Nonprecision approach costs are presented in appendix B.

The EMS interhospital transport mission could benefit greatly from the installation of nonprecision approaches to helipads. Whenever weather conditions are below the EMS operator's VFR minimums, the helicopter cannot fly directly from hospital to hospital. The mission must either be canceled or the helicopter must fly IFR from the base hospital to an airport near the transferring hospital. The helicopter can then use the approach to the airport. Either the patient will be brought by ground ambulance to the airport, or the helicopter may break off from the approach and fly SVFR to the transferring hospital. Either way, valuable time is lost. Furthermore, the helicopter will have the same two options when it returns to its base hospital. Appendix D fully develops the rationale used in developing the equation for computing the benefits for installing nonprecision approaches to hospital helipads.

The equation which will be used to calculate the helicopter air ambulance benefits is as follows:

Savings/Year = (Population)(Transports/Population/Year)(% Interhospital Transfers)(% Trauma Patients)(% Mortality Reduction)(% IFR wx/(1 - % IFR wx)(Value of Human Life), (Eq 16)

Where: Population = the population of the average EMS operator's cross-country operating area, approximately a 145 mile radius.

Transports/Population/Year = 50 (urban area) or 275 (rural area) transports per 100,000 population per year. This estimate was developed by Amherst Associates of Chicago, Illinois (reference 59). (Eq 17)

Note: (Population) X (Transports/Population/Year) = transports per year exists for 26 of the 50 sites chosen for analysis. The data was collected by the Journal of Air Medical Transport (JAMT) but is unpublished. The number of transports for the 10 cities with the highest number of EMS transports was published by JAMT in May 1990. The actual number of transports will be used for the sites for which that data exists.

(% Interhospital Transfers) = approximately 75 percent of all EMS missions are for interhospital transfers on a national basis. Regional averages are also available from the JAMT for the percent of interhospital transfers. The published regional averages will be used in calculating benefits.

(% Trauma Patients) = approximately 40 percent of all interhospital transports are for trauma patients with life-threatening injuries. This number was derived by the authors from conversations with physicians associated with helicopter EMS programs.

(% Mortality Reduction) = approximately 7.5 percent of the trauma patients transported on EMS helicopters would die without the benefit of a well-developed EMS system of which the helicopter is a critical element. The basis for this percentage is provided in appendix D.

(% IFR wx/(1 - % IFR wx)) = a correction factor for the number of missions affected by adverse weather conditions. The denominator (1 - % Weather) corrects the annual number of missions flown upward to the number of missions which would have been flown if weather conditions had been VFR 100 percent of the time. The numerator (% Weather) reduces the annual number of missions flown to the number possible in the local area with the weathe minimums discussed in section 8.1. Data on the local weather conditions is derived from the Airport Specific File (reference 14) using the methodology discussed in appendix E, weather data model.

(Value of Human Life) = $1,500,000 as per the report, "Economic Values For Evaluation of Federal Aviation Administration Investment and Regulatory Programs," and the update bulletin published in October 1990, APO Bulletin APO-90-1. (Note: This value is periodically updated.)

Note that this equation is different from all the other benefit equations. Benefits are not calculated on an individual mission basis. Rather, benefits are calculated based on the total of all EMS missions in a given area for an entire year. This is because it proved impossible to assign a probability of saving a life to an individual mission on a nationwide base. The most

accurate way to calculate benefits is to use actual data on transport/ population/year for each location.

8.3.5 <u>Point-In-Space Approaches (Benefit 9)</u>

This section presents the methodology for computing the delay reduction benefits realized by installing rotorcraft point-in-space approaches at heavily congested airports. The underlying concept assumes rotorcraft point-in-space approaches, when properly introduced at airports, would enable rotorcraft to perform instrument approaches without delaying fixed-wing aircraft performing the normal approach. Benefits will be computed by comparing the total delay times per busy IFR hour with and without rotorcraft in the normal approach pattern.

Two assumptions are required:

(1) 30 percent of rotorcraft operations at high activity airports are performed during "busy hours"; and

(2) rotorcraft routinely flying to high activity airports will fly IFR during busy IFR hours when weather is below 1,000 feet or 2 miles but at or above 200 feet and 1/2 mile. The point-in-space approach would be beneficial only when the weather is below 1,000 feet or 2 miles but at or above 466 feet and 3/4 mile (average nonprecision instrument approach minimums as identified in section 8.1.1).

The first assumption is also used in section 8.3.1 where the supporting data has been provided. Since transportation for business people needs to be reliable, rotorcraft operations must continue even (or especially) when weather is poor. Assumption 2 presumes rotorcraft performing these types of missions can fly IFR and are typically category I precision approach capable. This methodology will also assume cross-country day minimums are appropriate, since busy IFR hours primarily occur during the daylight hours and rotorcraft operations at high-activity airports are a mix between local and itinerant flights. Ceilings and visibility of 1,000 feet and 2 miles are therefore appropriate.

Six steps are required to perform the life cycle benefit/cost analysis of installing a rotorcraft point-in-space approach at a high activity airport:

1) compute the number of busy IFR hours per year when a rotorcraft point-in-space approach would be flown:

   Busy IFR Hours/Year = (Busy Hours/Year)(% IFR Weather), (Eq 18);

2) compute the total number of fixed-wing operations per busy IFR hour:

   Fixed-wing IFR Operations/Busy IFR Hour = (Total IFR Operations/ Busy IFR Hour) - (Rotorcraft IFR Operations/busy IFR Hour), (Eq 19);

3) determine the total delay times associated with flying the normal approach, both with and without rotorcraft;

4) determine the reduction in delay time:

Delay Reduction = (Delay with Rotorcraft) - (Delay Without Rotorcraft), (Eq 20);

5) find the total annual cost savings from the delay reduction:

Savings/Year = (Delay Reduction/Year)(Delay Costs), (Eq 21); and

6) compute the ratio of life cycle benefits to costs.

Step 1 - The frequency of a busy IFR hour when a rotorcraft point-in-space approach could be flown is determined based on established FAA methodology. Airports experience an average of 1,252 busy hours per year (based on a regression analysis of activity levels at 271 airports) (reference 47). This value, multiplied by the percent of time the weather is below 1,000 feet and 2 miles and at or above 466 feet and 3/4 mile (data taken from the FAA's Airport Specific File (reference 14)), will determine the number of busy IFR hours per year at an airport when IFR rotorcraft could perform a rotorcraft point-in-space approach.

Step 2 - The number of fixed-wing and rotary-wing operations per busy IFR-hour must be determined. The total number of IFR operations per year can be determined by looking up the number of annual instrument approaches at a specified airport (reported in the document, "FAA Air Traffic Activity - Calendar Year 1989" (reference 60)). Next, the number of rotorcraft operations (taken from FAA records, es imated by the local operators, or similar means) are subtracted. The number oi IFR busy hour operations excluding rotorcraft can then be determined by referencing table 16, a regression analysis performed by the FAA which relates the two variables (reference 47).

Since 30 percent of rotorcraft instrument operations are assumed to be performed during busy IFR hours, the number of rotorcraft operations per busy IFR hour can be estimated by:

Rotorcraft IFR Operations/Busy IFR Hour = (Rotorcraft IFR Operations/Year) (0.30 Busy IFR Operations/Total IFR Operations)(1 Year/1,252 Busy IFR Hours), (Eq 22)

TABLE 16 RELATIONSHIP BETWEEN BUSY IFR HOUR OPERATIONS AND ANNUAL INSTRUMENT OPERATIONS

RANGE OF ANNUAL INSTRUMENT OPERATIONS	IFR BUSY HOUR INSTRUMENT OPERATIONS
6,282 - 7,438	10
12,830 - 14,359	15
21,160 - 23,023	20
31,111 - 33,284	25
42,571 - 45,035	30
55,454 - 58,194	35
69,693 - 72,697	40
85,231 - 88,490	45
102,021 - 105,525	50
105,526 - 109,078	51
109,079 - 112,678	52
112,679 - 116,326	53
116,327 - 120,021	54
120,022 - 123,764	55
123,765 - 127,553	56
127,554 - 131,388	57
131,389 - 135,270	58
135,271 - 139,198	59
139,1 · 143,171	60
143,1' and over**	

** Busy hour instrument operations for higher activity levels may be found using the formula:

Busy Hour Instrument Operations = 0.05352138*(Annual Instrument Operations)$^{0.5921863}$ (Eq 23)

Step 3 - The total operational delay times per busy IFR hour can now be determined by referencing table 17 (a conservative estimate extrapolated from delay times provided in figure 3 of "Investment Criteria For Airport Surveillance Radar" (reference 47)). Total delay times without rotorcraft can then be taken directly from table 17. Interpolations may have to be performed as necessary. Delay times with rotorcraft must next be determined. The equivalent number of operations with rotorcraft is determined by using equation 24. Once the equivalent number of operations is known, re-enter table 17 to calculate the total delay times with rotorcraft.

Equivalent IFR Operations with Rotorcraft/Busy IFR Hour = (Fixed-Wing IFR Operations/Busy IFR Hour)) + (Touchdown Ratio)(Rotorcraft IFR Operations/Busy IFR Hour), (Eq 24)

TABLE 17 RELATIONSHIP BETWEEN DELAY TIME AND NUMBERS OF INSTRUMENT OPERATIONS (Refeɪence 47)

NUMBER OF OPERATIONS/ RUNWAY HOUR	TOTAL MINUTES OF DELAY/HOUR
10	10.6
15	22.3
20	41.5
25	68.1
30	95.1
35	132.8
40	185.5
45	259.0
50	361.7
51	386.7
52	413.4
53	441.9
54	472.4
55	505.1
56	540.0
57	577.2
58	617.1
59	659.7
60	705.3
61	754.0
62	806.1
63	861.8
64	921.3
65	985.0
66	1053.0
67	1125.7
68	1203.5
69	1286.6
70	1375.5
71	1470.5
72	1572.0
73	1680.6
74	1796.7
75	Over Capacity

The delay time with rotorcraft equation is necessary because the total delay time values used in this methodology are approximated based on a weighted average using an aircraft activity level mix of 80 percent transport aircraft (average approach airspeed of 125 knots) and 20 percent general aviation aircraft (average approach airspeed of 90 knots). Because of the different approach speeds, the time between touchdown of a general aviation aircraft followed by a transport is 1.44 minutes, and the time between touchdown of a transport followed by a general aviation aircraft (including rotorcraft) is 3.48 minutes (reference appendix A). Table 18 captures this difference in

times between touchdown; for any mix of transport aircraft and general aviation aircraft (column 1), that it takes longer for a rotorcraft to land (column 3) than the average time between touchdowns at an airport (column 2). This time increase is captured as a ratio (column 4) and used to adjust the number of operations per hour to find the delay without a rotorcraft point-in-space approach.

TABLE 18 AVERAGE TIME BETWEEN TOUCHDOWN

AIRCRAFT MIX (TRANSPORT/GEN. AVIATION)	AVERAGE TIME BETWEEN TOUCHDOWN	TIME BETWEEN TOUCHDOWN (AIRPLANE FOLLOWED BY ROTORCRAFT)	TOUCHDOWN RATIO (ROTORCRAFT/AIRPLANE)
90/10	1.61	3.10	1.93
80/20	1.74	2.92	1.68
60/40	1.89	2.57	1.36
20/80	1.77	1.86	1.05

The equivalent IFR operations with rotorcraft per busy IFR hour is computed by using equation 24. The appropriate touchdown ratio is taken from table 18.

The total minutes of delay/hour taken from table 17 equals total approach and departure delay time. Dividing this value by two conservatively approximates the total approach delay time at an airport, because as airport capacities are reached, landing delays tend to exceed takeoff delays. Therefore, half of the total operational delay times will give a slightly conservative estimate of the total approach delay time.

Step 4 - The reduction in total approach delay times from providing rotorcraft with point-in-space approaches can be computed by subtracting the total approach delay time without rotorcraft from the total approach delay time with rotorcraft.

Delay Reduction/Hour = (Equivalent Delay With Rotorcraft/Hour) - (Total Delay Without Rotorcraft/Hour), (Eq 25)

Step 5 - The total annual cost savings are determined by multiplying the delay reduction per busy IFR hour (step 4) by the number of busy IFR hours (step 1) by the weighted average total delay costs per hour:

Savings/Year = (Delay Reduction/Hour) (Busy IFR Hours/Year)(Delay Costs/Hour), (Eq 26)

Average total delay costs are summarized in table 19.

TABLE 19 DELAY COSTS PER HOUR BY USER CLASS
(1990 Dollars)

USER CLASS	VARIABLE OPERATING COSTS	NUMBER OF PASSENGERS	VALUE OF PASSENGERS/ TIME/HOUR	TOTAL DELAY COSTS/HOUR
Air Carrier	$1635	105.2	$38	$5621
General Aviation	117	2.8	38	223
Rotorcraft*	187	3.1	85	450
90-10 mix (AC/GA)	1481	95.0	38	5081
80-20 mix (AC/GA)	1330	84.7	38	4539
60-40 mix (AC/GA)	1026	64.2	38	3459
20-80 mix (AC/GA)	420	23.3	38	1299

* based on the 1990 forecasted operational mix of commuter, corporate/executive, business, and air taxi rotorcraft missions (reference 49).

Step 6 - To perform the life cycle benefit/cost analysis, a 15-year life cycle will be assumed, discounted at a rate of 10 percent with a mid-year convention. Total 15-year life cycle costs will be $29,784 for nonprecision approaches not requiring the installation of additional electronics (see appendix B, page B-2).

The total value of the delay reduction is the sum of the discounted annual delay reductions. Annual delay reductions should be computed individually when large increases in rotorcraft activity are expected. This report will assume the delays in the baseline year are representative of the delays for every year. Based on this, the total life cycle benefits can be computed by multiplying the baseline delay reduction benefit by 7.977, as described in the FAA's "Economic Analysis of Investment and Regulatory Decisions" (reference 19).

A comprehensive example of applying this point-in-space benefit methodology at a congested airport is presented in figure 29.

To standardize the methodology and simplify the computations, a number of secondary benefits and costs from using a rotorcraft point-in-space approach will not be computed. These are listed below:

1) 70 percent of the rotorcraft operations at high-activity airports occur during non-busy hours. Aircraft may still experience delays during these times, and the removal of a rotorcraft from the approach pattern would probably decrease delays;

2) ultimate aircraft capacities at airports would increase by almost twice the number of rotorcraft removed from the instrument approach pattern. At times when delays are unusually high, fewer scheduled transport flights would be canceled;

Assumptions:	
Probability of the weather being below 1,000 feet ceiling and 1 mile visibility:	8.00%
Probability of the weather being below 466 feet ceiling and 3/4 mile visibility:	2.00%
Busy hours per year:	1252 hours
Fixed-wing annual instrument operations:	120,000 operations per year
Helicopter annual instrument operations:	3,000 operations per year
Annual growth rate for all operations:	0% annual growth
Ratio of air transport to general aviation operations:	80% air transport/20% general aviation
Step 1 calculations:	
Percent of time weather is between 466 feet and 3/4 mile and 1,000 feet and 1 mile:	8% - 2% = 6%
Busy IFR hours per year:	(1,252 hours) * 6% = 75 hours
Step 2 calculations:	
From table 16, find fixed-wing IFR busy hour operations:	Entering table 16 with 120,000 annual instrument operations yields 54 IFR busy hour operations without rotorcraft.
Determine rotorcraft IFR operations per busy hour:	3,000 rcft ops/yr * 30% in busy hour/1,252 busy hours = 0.72 rcft IFR busy hour operations.
Step 3 calculations:	
Determine fixed-wing delay from table 17:	Entering table 17 with 54 IFR busy hour operations yields 472.2 minutes of delay per hour. Assuming half of these apply to approaches yields 236.2 minutes of delay per hour for approaches.
Determine equivalent operations per IFR hour with rotorcraft:	Applying equation 24 using a touchdown ratio of 1.68 from table 18 yields 54 fixed-wing IFR operations/busy hour plus 0.72 rcft IFR busy hour operations times 1.68 touchdown ratio equals 55.2 operations per busy hour with rotorcraft.

FIGURE 29 EXAMPLE OF A POINT-IN-SPACE APPROACH BENEFIT AT A CONGESTED AIRPORT

Determine fixed-wing plus rotorcraft delay from table 17:	Enter table 17 with 55.2 IFR busy hour operations; interpolation yields 512.0 minutes of delay per hour. Assuming half of these apply to approaches yields 256.0 minutes of delay per hour for appoaches with rotorcraft.
Step 4 calculations:	
Determine delay reduction with use of a point-in-space approach for rotorcraft:	256.0 minutes of delay with rotorcraft minus 236.2 minutes of delay without rotorcraft yields 19.8 minutes of delay reduction per IFR busy hour.
Step 5 calculations:	
Determine annual IFR busy hour delay reduction:	19.8 minutes delay reduction/hr times 75 busy IFR hours/year divided by 60 minutes/hour equals 24.75 hours of annual delay reduction.
Determine annual dollar benefit:	From table 19 for an 80/20 aircraft mix obtain $5,081 delay costs per hour. Multiply 24.75 hours savings times $5,081 to yield 125.8 thousand dollars per year.
Determine 15-year life cycle benefit:	Multiply 125.8 thousand dollars per year by 7.977 multiplier to convert constant annual dollars to a 15-year life cycle to yield 1.00 million dollars 15-year life cycle benefit.
Determine benefit/cost ratio:	From appendix B, the cost of a point-in-space approach is assumed to cost about the same as a Loran-C non-precision approach, which is $29,784. The benefit/cost ratio is 33.7.

FIGURE 29 EXAMPLE OF A POINT-IN-SPACE APPROACH BENEFIT AT A CONGESTED AIRPORT (Continued)

3) reducing the number of aircraft in a traffic pattern decreases the likelihood of a midair collision. Since the number of IFR rotorcraft operations is considered to be relatively small, the benefits from increased safety are assumed to be negligible;

4) while the Air Traffic Control Handbook (reference 37) states that controllers should "provide air traffic control service to aircraft on a first come, first served basis as circumstances permit...," some controllers elect to delay general aviation aircraft (and rotorcraft) rather than delay transports. This practice could reduce the size of the benefit. Since this is not an authorized procedure, no corrections will be incorporated in the report;

5) a rotorcraft point-in-space approach may require a rotorcraft to travel an extra distance, as the missed approach point must be at least 2,600 feet from the landing area and may be a number of miles away from the airport. For this report, the additional flight time is considered to be negligible; and

6) lastly, rotorcraft transportation is primarily used because it is convenient and saves time for passengers. Reducing the time rotorcraft are delayed would enhance the rotorcraft operators' competitive posture and, therefore, increase their business. For this report, the increase in business is not included in the benefits calculation.

8.3.6 Revised Air Traffic Control Procedures (Benefit 10 and 11)

Computing the cost savings from providing a rotorcraft intercept point or using 2.5 miles separation (section 8.1.6) requires a methodology and assumptions similar to section 8.3.5. Six steps need to be performed:

1) compute the number of busy IFR hours per year when a rotorcraft point-in-space approach could be flown:

   Busy IFR Hours/Year = (Busy Hours/Year)(% IFR Weather), (Eq 27);

2) compute the total number of fixed-wing operations per busy IFR hour:

   Fixed-wing IFR Operations/Busy IFR Hour = (Total IFR Operations/Busy IFR Hour) - (Rotorcraft IFR Operations/Busy IFR Hour), (Eq 28);

3) determine the total delay time with and without the changed procedure from table 17;

4) determine the reduction in delay time:

   Delay Reduction = (Delay Without Procedure) - (Delay With Procedure), (Eq 29);

5) find the total annual cost savings:

Savings/Year = (Delay Reduction/Year)(Delay Costs), (Eq 30); and

6) compute the life cycle benefits for each procedural change.

Step 1 - The frequency of a busy IFR hour can be determined by multiplying 1,252 busy hours per year (from section 8.3.5) by the percentage of time the weather is below 1,000 feet and 2 miles but at or above 200 feet and 1/2 mile (refer to step 1 in section 8.3.5).

Step 2 - The number of fixed-wing and rotary-wing operations per busy IFR hour should be computed using the same procedures as in step 2 from section 8.3.5.

Step 3 - The total delay time per busy IFR hour without the changed procedure is computed as in step 3 of section 8.3.5. The total delay time with the improved procedures is computed by again referencing table 17 after revising the value of total operations per busy IFR hour with the new touchdown ratios found in tables 20 and 21.

TABLE 20 AVERAGE TIME BETWEEN TOUCHDOWN WITH A ROTORCRAFT INTERCEPT POINT AT THE FINAL APPROACH FIX

AIRCRAFT MIX (TRANSPORT/GEN. AVIATION)	AVERAGE TIME BETWEEN TOUCHDOWN	TIME BETWEEN TOUCHDOWN (AIRPLANE FOLLOWED BY ROTORCRAFT)	TOUCHDOWN RATIO* (ROTORCRAFT/ AIRPLANE)
90/10	1.61	2.79	1.73
80/20	1.74	2.64	1.51
60/40	1.89	2.36	1.25
20/80	1.77	1.79	1.01

Reference: Appendix A, Computations of Timesavings for Procedural Changes.

*The touchdown ratio is the ratio of the total time required for a rotorcraft and an in-trail airplane to touchdown to the total time required for two airplanes to touchdown.

TABLE 21 AVERAGE TIME BETWEEN TOUCHDOWN WITH 2.5 MILES SEPARATION

AIRCRAFT MIX (TRANSPORT/GEN. AVIATION)	AVERAGE TIME BETWEEN TOUCHDOWN	TIME BETWEEN TOUCHDOWN (AIRPLANE FOLLOWED BY ROTORCRAFT FOLLOWED BY AIRPLANE)	TOUCHDOWN RATIO* (ROTORCRAFT/ AIRPLANE)
90/10	1.61	4.04	1.25
80/20	1.74	3.93	1.13
60/40	1.89	3.75	0.99
20/80	1.77	3.36	0.95

Reference: Appendix A, Computations of Timesavings for Procedural Changes.

*The touchdown ratio is the ratio of the total time required for a rotorcraft and an in-trail airplane to touchdown to the total time required for two airplanes to touchdown.

STEP 4 - The reduction in total approach time from incorporating either procedure can be computed by subtracting the total delay time with the improved procedures from the total delay time without the improved procedures:

Delay Reduction/Hour = (Delay without Procedure/Hour) - (Delay with Procedure/Hour), (Eq 31)

STEP 5 - The total annual cost savings can be determined by multiplying the delay reduction (step 4) by the number of busy IFR hours (step 1) by the weighted average total delay costs per hour (table 19):

Savings/Year = (Delay Reduction/Hour)(Busy IFR Hours/Year)(Delay Costs/Hour), (Eq 32)

STEP 6 - Only the life-cycle benefits realized from these procedural changes will be computed. Life cycle costs are limited to the research and development costs required to validate the procedures. These are one-time, fixed costs and would be minimal and difficult to capture.

8.4 SUMMARY

The benefits presented in this section meet three criteria: they will benefit rotorcraft operations (and, in some instances, fixed-wing airplanes), they require an investment of capital, and they are implementable. Benefits not presented are those readily implementable, such as those achieved through letters of agreement, and those that are very futuristic, such as autonomous IFR operations (the ability to fly in IMC with the pilot using avionics to provide separation). It is believed this methodology will provide a proper focus and will make the benefit/cost computations conservative and meaningful. The final report will apply these improvements to the 50 sites selected in section 4.0 and will quantify the benefits. The benefit/cost ratios will then identify the most important site specific improvements that should be made.

LIST OF REFERENCES

1. "Airway Planning Standard Number One - Terminal Air Navigation Facilities and Air Traffic Control Services," FAA Order 7031.2C, Federal Aviation Administration, November 1984.

2. Blumen, Ira J., M.D., "Taking to the Skies," Emergency, November 1989, p. 34.

3. Boyd, Carl R., et al, "Outcome of Trauma Patients Transported by a Rural Hospital-Based Helicopter EMS Program," Hospital Aviation, July 1988, p. 14.

4. "Code of Federal Regulations, Title 14 Aeronautics and Space," Parts 60 to 139, Office of the Federal Register, National Archives and Records Administration, January 1989.

5. Moylan, Joseph A., M.D., "Impact of Helicopters on Trauma Care and Clinical Results," Annals of Surgery, Volume 208, Number 6, December 1988, p. 67.

6. "NAS System Specification, Vol. I, Functional and Performance Requirements for the National Airspace System," Federal Aviation Administration, March 1989.

7. "National Airspace System Level I Design Document," NAS-DD-1000, Federal Aviation Administration, SCN 20, May 1990.

8. "National Airspace System Plan: Facilities, Equipment, Associated Development and Other Capital Needs," Federal Aviation Administration, September 1989.

9. Rhee, K., et al, "Predicting the Utilization of Emergency Medical Services: An Approach Based on Need," Annals of Emergency Medicine, October 1984, p. 916.

10. "Rotorcraft Low Altitude CNS Benefit/Cost Analysis: Rotorcraft Operations Data," First Interim Report, DOT/FAA/DS-89/9, prepared by Systems Control Technology, Inc. for the Federal Aviation Administration, September 1989.

11. "Rotorcraft Master Plan," Federal Aviation Administration, November 1990.

12. "The FAA Plan for Research, Engineering, and Development, Vol. II: Project Descriptions," Federal Aviation Administration, January 1989.

13. Sakrison, David, "To Fly or Not to Fly," Journal of Emergency Medical Services, November 1986, p. 43.

14. Airports File, National Flight Data Center, January 1989.

15. "Safety Through Technical Statistics (STATS)," Helicopter Foundation International, August 1988.

16. "1990 Helicopter Annual," Helicopter Association International, January 1990.

17. Data on Gulf of Mexico Helicopter Operations, Helicopter Safety Advisory Conference, April 1990.

18. Wong, Emily P., "Development of Revised and Expanded Airport Specific File Data for the Airport Criteria Data System," DTFA01-84-01020, December 1985.

19. "Economic Analysis of Investment and Regulatory Decisions - A Guide," FAA-APO-82-1, Federal Aviation Administration, January 1982.

20. McDaniel, James and Mayo, Harkey, "Vertical Flight Passenger Service in the Early 21st Century," Vertiflite, January/February 1990, p. 16.

21. Godar, Susan, "Helicopter Forecast," Vertiflite, January/February 1990, p. 8.

22. Rickey, Patricia, "Corporate Helicopter Survey," Rotor & Wing International, October 1989, p. 40.

23. Rickey, Patricia, "Civil Markets: Planning for Slow, Steady Growth," Rotor & Wing International, January 1990, p. 26.

24. "General Aviation Activity and Avionics Survey," FAA-MS-88-5, Federal Aviation Administration, November 1988.

25. "Future Aviation Activities - Sixth International Workshop," National Academy of Sciences, Transportation Research Board, No. 352, February 1990.

26. Geisinger, Kenneth, "Airline Delay: 1976-1986," Federal Aviation Administration, September 1988.

27. Collett, Howard, "Air Medical Helicopter Transport," Hospital Aviation, July 1988, p. 5.

28. "FAA Aviation Forecasts, FAA-APO-88-1," Federal Aviation Administration, February 1988.

29. "FAA Aviation Forecasts," FAA-APO-90-1, Federal Aviation Administration, March 1990.

30. "FAA Statistical Handbook of Aviation," AMS-420, Federal Aviation Administration, 1987-89.

31. "Thirteenth Annual FAA Aviation Forecast Conference Proceedings," FAA-APO-88-2, Federal Aviation Administration, February 1988.

32. "Fifteenth Annual FAA Aviation Forecast Conference Proceedings," FAA-APO-090-2, Federal Aviation Administration, March 1990.

33. Baxt, W.G., MD, "Hospital-Based Rotorcraft Aeromedical Emergency Care Services and Trauma Mortality: A Multicenter Study," Annals of Emergency Medicine, September 1985, p. 859-864.

34. Rhee, K., MD, "Differences in Air Ambulance Patient Mix Demonstrated by Physiologic Scoring," Annals of Emergency Medicine, May 1990, p. 552-556.

35. Champion, H.R., et al, "An Anatomic Index of Injury Severity," Journal of Trauma, 1980, p. 197-202.

36. Boyd, C., MD, "Evaluating Trauma Care: The TRISS Method," The Journal of Trauma, April 1987, p. 370-374.

37. "Air Traffic Control," FAA Handbook 7110-65F, September 21, 1989.

38. "Facility Operation and Administration," FAA Handbook 7210.31, February 9, 1989.

39. Baxt, W.G., MD, "The Impact of a Rotorcraft Aeromedical Emergency Care Service on Trauma Mortality," Journal of American Medical Association, June 10, 1983, p. 3047-3051.

40. Toycen, T., ME, abstract of unpublished report "Comparison of Outcome of Major Trauma Patients Transported by Air Versus Ground," Journal of Air Medical Transport, October 1990, p. 82.

41. "Application of the Microwave Landing System to Helicopter Operations," DOT/FAA/RD-82/40, Federal Aviation Administration, September 1982.

42. Pepe, P.E., et al, "Prehospital Management of Trauma: A Tale of Three Cities," Annals of Emergency Medicine, December 1986, p. 1484-1486.

43. Burney, R.E., et al, "Ground Versus Air Transport of Trauma Victims: Medical and Logistics Considerations," Annals of Emergency Medicine, December 1986, p. 1491-1498.

44. Editorial, Journal of Trauma, April 1987.

45. "Air Ambulance Helicopter Operational Analysis," DOT/FAA/RD-91/7, Federal Aviation Administration, March 1991.

46. Mansfield, E., "Statistics for Business and Economics," Norton & Company, New York, 1980.

47. "Investment Criteria for Airport Surveillance Radar (ASR/ATCRBS/ARTS)," FAA-APO-83-5, Federal Aviation Administration, May 1983.

48. "Establishment and Discontinuance Criteria for Runway Visual Range (RVR) at Category 1 Precision Landing System Runway," FAA-APO-87-9, January 1987.

49. "Economic Values for Evaluation of Federal Aviation Administration Investment and Regulatory Programs," FAA-APO-89-10, October 1989.

50. "1990 Program Survey," The Journal of Air Medical Transport, May 1990.

51. "Investigation of Helicopters in Public Service: Requirements and Contributions," NAS2-10411, November 1980.

52. Lorge, Frank, "LORAN-C Offshore Flight Following (LOFF) in the Gulf of Mexico," DOT/FAA/CT-TN88/8, February 1988.

53. Matthews, Raymond H. and Sawyer, Brian M., "Rotorcraft Terminal ATC Route Standards," DOT/FAA/RD-90/18, August 1991.

54. "Aviation System Capital Investment Plan," Federal Aviation Administration, 1990.

55. "NAS System Specification Volume I, General Appendix II NAS Architecture," NAS-SS-1000, Federal Aviation Administration.

56. "United States Standard for Terminal Instrument Procedures (TERPS)," FAA Handbook 8260.3B, July 1976.

57. Peisen, D.J. and Newman, R.B., "Indianapolis Downtown Heliport - Operations Analysis and Marketing History," DOT/FAA/DS-89/32, Systems Control Technology, August 1991.

58. Peisen, D.J., "New York Downtown (Wall Street) Heliport - Operations Analysis," DOT/FAA/RD-91/12, September 1991.

59. Williams, Louis, "Helicopter Transport Takes Off: Should Your Hospital Invest in the Air Ambulance Business?" Amberst Associates, Chicago, IL, 1991, 6-11.

60. "FAA Air Traffic Activity - Calendar Year 1989," Federal Aviation Administration, 1991.

61. "OMB Inflation Rate Guide," July 1990.

62. "Establishment and Discontinuance Criteria for Automated Weather Observing Systems," FAA-APO-83-6, Federal Aviation Administration, 1983.

63. "AOPA's Aviation USA," ISSN: 0271-065x, 1990.

64. "Call for Estimates," Air/Ground Communications Branch, ANC-130, Federal Aviation Administration, 1991.

65. "ASR 7 & 8 Surveillance Radar - ASR9," NAS Change Proposal 9710, 1986.

66. "Economic Values for Evaluation of Federal Aviation Administration Investment and Regulatory Programs," FAA-APO-89-10, Federal Aviation Administration, October 1989.

67. "Economic Values for Evaluation of Federal Aviation Administration Investment and Regulatory Programs," APO Bulletin, APO-90-1, Federal Aviation Administration, October 1990.

68. Martin, D.E., "Climatic Models that will Provide Timely Mission Success Indicators for Planning and Supporting Weather Sensitive Operations," Air Force Geophysics Laboratory, F19628-77-C-0032, September 1978.

69. Champion, H.R., "Trauma Severity Scoring to Predict Mortality," World Journal of Surgery, 1983, p. 4-11.

LIST OF ACRONYMS

AC	Advisory Circular
ADS	Automatic Dependent Surveillance
AGL	Above Ground Level
ALS	Advanced Life Support
AOPA	Aircraft Owners and Pilots Association
ARSA	Airport Radar Service Area
ASF	Airport Specific File
ATC	Air Traffic Control
ATCBI	Air Traffic Control Beacon Interrogator
ATCRBS	Air Traffic Control Radar Beacon System
CAT	Category
CEO	Chief Executive Officer
CFR	Code of Federal Regulations
CIP	Capital Investment Plan
CMSI	Climatic Mission Success Indicators
CNS	Communications, Navigation, and Surveillance
CONUS	Conterminous United States
DEC	Digital Equipment Corporation
DOD	Department of Defense
EMS	Emergency Medical Service
EMS/H	Emergency Medical Service/Helicopter
EMT	Emergency Medical Technician
FAA	Federal Aviation Administration
FAF	Final Approach Fix
FLIR	Forward Looking Infrared
FOV	Field of View
GPS	Global Positioning System
HAI	Helicopter Association International
HAT	Height Above Touchdown
HDD	Head-Down Displays
HF	High Frequency
HFI	Helicopter Foundation International
HSAC	Helicopter Safety Advisory Conference
HUD	Head's-Up Displays
ICAO	International Civil Aviation Organization
IFR	Instrument Flight Rules
ILS	Instrument Landing System
IMC	Instrument Meteorological Conditions
IR	Infrared
JFK	John F. Kennedy Airport
LGA	LaGuardia Airport
LLLTV	Low Light Level Television
LOFF	LORAN Offshore Flight Following
LORAN	Long Range Navigation
MEA	Minimum En Route Altitude
MLS	Microwave Landing System
MMW	Millimeter-Wave
MOCA	Minimum Obstruction Clearance Altitude
MSL	Mean Sea Level

MTOS	Major Trauma Outcome Study
Mode S	Mode Select
NAWD	National Average Weather Data
NAS	National Airspace System
NFDC	National Flight Data Center
NM	Nautical Mile
NVG	Night Vision Goggles
OASYS	Obstacle Avoidance System
OMB	Office of Management and Budget
OSAP	Offshore Standard Approach Procedures
PCRM	Parallel/Converging Runway Monitor
PRM	Parallel Runway Monitor
RCAG	Remote Communications Air/Ground Facility
RCF	Remote Communications Facility
R,E&D	Research, Engineering and Development
RMP	Rotorcraft Master Plan
RTCA	Radio Technical Commission for Aeronautics
SAR	Search and Rescue
SAWRS	Supplementary Aviation Weather Reporting Station
SID	Standard Instrument Departures
STAR	Standard Terminal Arrivals
SVFR	Special Visual Flight Rules
TACAN	Tactical Air Navigation
TCA	Terminal Control Area
TCAS	Traffic Alert and Collision Avoidance System
TEC	Tower En Route Control
UHF	Ultra High Frequency
VFR	Visual Flight Rules
VHF	Very High Frequency
VMC	Visual Meteorological Conditions
VOR	Very High Frequency Omnidirectional Range
VOR/DME	VHF Omnidirectional Range/Distance Measuring Equipment
VORTAC	VOR Collocated with TACAN
W/C/A	Warning/Caution/Advisory

APPENDIX A
COMPUTATION OF TIMESAVINGS FOR PROCEDURAL CHANGES

Three ATC procedural changes discussed in section 8.1 are developed fully in this appendix. Section A.1 discusses the computation of time savings attributable to the use of a point-in-space approach. Section A.2 discusses the time savings attributable to the use of a rotorcraft intercept point for IFR approach procedures. Section A.3 discusses the time savings attributable to the use of reduced in-trail separation distances from 3 to 2 1/2 miles and a rotorcraft intercept point.

All of the calculations are based on the following assumptions: 1) the fixed-wing traffic is traveling at 125 knots; 2) the rotorcraft is traveling at 90 knots; and 3) with regard to the distances depicted in figure 27, the intercept point is 8 nautical miles (nm) from the runway threshold, the gate is 7 nm from the threshold, and the final approach fix (FAF) is 5 nm from the threshold.

A.1 THRESHOLD CROSSING TIMES WITH AND WITHOUT A POINT-IN-SPACE APPROACH

Without a point-in-space approach, once airplane #1 reaches the intercept point it will take nearly 4 minutes to reach the runway threshold (8 nm X 1 hr/125 nm X 60 min/1 hr = 3.84 min). For the purposes of this example, the time at which airplane #1 crosses the threshold is defined as time 0. Airplane #2 is following #1 in-trail by 3 nm, or 1.44 minutes, and will cross the threshold at time 1.44 minutes. Airplane #3 is following #2 in-trail by 1.44 minutes and will cross the threshold at time 2.88 minutes. At the point that #3 is at the intercept point, the rotorcraft is inserted into the approach traffic. The helicopter must be separated from #3 by at least 3 nm, and to this must be added the 8 nm from the intercept point to the threshold for a total of 11 nm. Thus, the rotorcraft will take 7.33 minutes to reach the threshold (11 nm X 60 min/90 nm = 7.33 min). For 3.84 of the 7.3 minutes, the rotorcraft and #3 are on the approach course at the same time. Therefore, only 3.49 minutes (7.33 - 3.84 = 3.49 min) of the rotorcraft approach time is delay. The rotorcraft will cross the threshold at time 6.37 minutes. Airplane #4 is following the rotorcraft in-trail and will cross the threshold at time 7.81 minutes, 1.44 minutes after the rotorcraft crosses the threshold.

With a point-in-space approach, the threshold crossing times of the first three planes will be the same as described above. However, the rotorcraft will fly directly to the airport without ever entering the approach path used by the fixed-wing aircraft. Therefore, rotorcraft will not experience any delay waiting for a clearance from ATC to land, and the fixed-wing aircraft will not be delayed for the 3.49 minutes required for the slower rotorcraft to complete the standard approach. Airplane #4 will cross the threshold 1.44 minutes after airplane #3 at time 4.32 minutes.

A.2 THRESHOLD CROSSING TIMES WITH A ROTORCRAFT INTERCEPT POINT

The threshold crossing times of the first three airplanes are the same as calculated in section A.1. The introduction of a rotorcraft intercept point at the FAF will result in the following time reduction. Once airplane #3 reaches the FAF, it will cross the threshold after another 2.4 minutes of

flight (5 nm X 60 min/125 nm = 2.4 min). At the point that airplane #3 is at the FAF, the rotorcraft is inserted into the approach traffic. The rotorcraft must be separated from #3 by at least 3 nm, and to this must be added the 5 nm from the FAF to the threshold for a total of 8 nm. Thus, the rotorcraft will take 5.33 minutes to reach the threshold (8 nm X 60 min/90 nm = 5.3 min). For 2.4 of the 5.33 minutes the rotorcraft is on the approach course airplane #3 will also be on the approach course. Thus, only 2.93 minutes of the rotorcraft approach time is delay (5.33 - 2.4 min = 2.93 min), and the rotorcraft will cross the threshold at time 5.81 minutes. Airplane #4 is following the rotorcraft in-trail by 1.44 minutes and will cross the threshold at time 7.25 minutes.

A.3 THRESHOLD CROSSING TIMES WITH REDUCED SEPARATION INSIDE THE FAF

The reduction of in-trail separation requirements from 3 nm to 2 1/2 nm between rotorcraft and in-trail, fixed-wing aircraft inside the FAF will result in the following time reductions. Once airplane #3 reaches the FAF, it will cross the threshold after another 2.4 minutes of flight. At the point that airplane #3 is at the FAF, the rotorcraft is inserted into the approach traffic. It is not possible to decrease the separation distance between a leading large or heavy fixed-wing aircraft and an in-trail rotorcraft because of wake turbulence separation requirements. The rotorcraft will be separated from #3 by 3 nm, and to this must be added the 5 nm from the FAF to the threshold for a total of 8 nm. Thus, the rotorcraft will take 5.33 minutes to reach the threshold (8 nm X 60 min/90 nm = 5.33 min). For 2.4 of the 5.33 minutes the rotorcraft is on the approach course, airplane #3 will also be on the approach course. Thus, only 2.93 minutes of the rotorcraft approach time is delay (5.33 - 2.4 min = 2.93 min), and the rotorcraft will cross the threshold at time 5.81 minutes. Airplane #4 is following the rotorcraft in-trail by 2 1/2 nm, or 1.2 minutes, and will cross the threshold at 7.01 minutes.

APPENDIX B
COST DATA SUPPORT

To determine the costs associated with various identified benefits, the method described in the FAA's "Economic Analysis of Investment and Regulatory Decisions" (reference 19) was used. All costs have been converted to 1990 dollars using the inflation rate specified by the "OMB Inflation Rate Guide," 7 July 1990 (reference 61). All cost data is provided in table B-1.

B.1 SUPPLEMENTARY AVIATION WEATHER REPORTING STATION (SAWRS)

It was decided to use a SAWRS instead of the more expensive ASOS, because most of the installations would be at hospitals and heliports where the cost of the automated weather system would be a prime consideration. The costs associated with a SAWRS were obtained from "Establishment and Discontinuance Criteria for Automated Weather Observing Systems," FAA-APO-83-6 (reference 62). This reference breaks the costs down into two areas: facilities and equipment, and operations and maintenance. Initial costs and annual costs in both of these categories were escalated from 1981 to 1990 dollars: the annual costs were then escalated again over a 15-year life cycle. The present value cost for a SAWRS is $8,914 in 1990 dollars.

B.2 LORAN-C NONPRECISION APPROACH

The costs associated with a LORAN-C nonprecision approach are for 3 main items: 1) the LORAN-C receiver, 2) the development and annual flight checking of the approach procedure, and 3) the SAWRS. The cost of the lowest price receiver currently certified for use on nonprecision approaches is $3,295, as per the 1990 edition of AOPA's "Aviation USA" (reference 63). The estimated initial cost of developing an approach procedure is $3,738, and the annual costs of flight checking the approach are estimated at $1,734. These cost estimates were provided by the MLS/LORAN-C/GPS branch, ANN-150, of the FAA. Annual costs have been escalated at 10 percent per year for 15 years to arrive at the present value costs for annual expenditures. The SAWRS costs were developed in section D.1. The present value cost for a LORAN-C nonprecision approach is $29,784 in 1990 dollars.

B.3 REMOTE COMMUNICATION AIR/GROUND FACILITY IN THE GULF OF MEXICO

The costs associated with a remote communications air/ground facility (RCAG) in the Gulf of Mexico were obtained from the Air/Ground Communication Branch, ANC-130, at FAA Headquarters. The costs are published in their "Call for Estimates" (reference 64) for fiscal year 1991. The costs are broken down into two areas: facilities and equipment, and operations and maintenance. The operations and maintenance costs have been escalated to obtain the present value of the 15-year life cycle cost. The total present value cost of a RCAG in the Gulf is $573,003 in 1990 dollars.

B.4 REMOTE TRANSMITTER/RECEIVER

The costs associated with a remote transmitter/receiver (RTR) were obtained from the Air/Ground Communication Branch, ANC-130, at FAA Headquarters. The costs are published in their "Call for Estimates" (reference 64) for fiscal year 1991. The costs are broken down into two

TABLE B-1 COST DATA

	INITIAL COSTS	ANNUAL COSTS	PRESENT VALUE
NON-GOVERNMENT SUPPLEMENTARY AVIATION WEATHER REPORTING SYSTEM			
Facilities & Equipment			
Equipment	$2,571		$2,571
Initial Spares	$643		$643
Total	$3,213		$3,213
Operations & Maintenance			
Personnel			
Observation	$0	$0	$0
Maintenance	$0	$406	$3,239
Spares Inventory	$0	$308	$2,462
Communications	$0	$0	$0
Facilities	$0	$0	$0
Total	$0	$714	$5,701
TOTAL			$8,914
LORAN-C NONPRECISION APPROACH			
LORAN-C Receiver	$3,295		$3,295
Approach Plate	$3,738	$1,734	$17,575
SAWRS	$3,213	$5,701	$8,914
Total	$10,246	$7,435	$29,784
REMOTE TRANSMITTER/RECEIVER IN THE GULF OF MEXICO			
Facilities & Equipment			
Install & Construction	$165,000	$0	$165,000
2 VHF Transceivers	$104,700	$0	$104,700
Cables	$2,460	$0	$2,460
EMI Equipment Racks	$4,000	$0	$4,000
RF Ground	$11,000	$0	$11,000
Battery Power Backup	$43,000	$0	$43,000
Remote Control Equipment	$64,000	$0	$64,000
Antennas @ 2 Each	$2,800	$0	$2,800
Spare Parts	$44,130	$0	$44,130
Spare Parts Peculiar	$13,578	$0	$13,578
Factory Inspection	$10,184	$0	$10,184
Shipping	$10,184	$0	$10,184
F&E Training	$13,578	$0	$13,578
Total	$488,614	$0	$488,614
Operations & Maintenance		$10,575	$84,389
TOTAL			$573,003
REMOTE COMMUNICATIONS AIR/GROUND FACILITY			
Facilities & Engineering			
Equipment at Facility	$191,657		
Remote Control Equipment	$71,093		
Total	$262,750	$0	$262,750
Operations & Maintenance	$0	$18,851	$150,431
TOTAL			$413,181

TABLE B-1 COST DATA (CONTINUED)

	INITIAL COSTS	ANNUAL COSTS	PRESENT VALUE
LORAN-C OFFSHORE FLIGHT FOLLOWING			
HOST Software Modification			$500,000
DARC Software Modification			$350,000
Communication Processor			$500,000
Radar Message Converter			$300,000
Total			$1,650,000
AIRPORT SURVEILLANCE RADAR - 9			
Facility & Engineering			
Equipment	$2,702,400		$2,702,400
Freight	$81,100		$81,100
Spares	$1,723,900		$1,723,900
Software	$343,400		$343,400
Factory Inspection	$122,700		$122,700
Installation	$1,553,900		$1,553,900
Documentation	$257,900		$257,900
Technical Support	$13,500		$13,500
Test Equipment	$225,200		$225,200
Total	$7,024,000		$7,024,000
Operations & Maintenance	$24,700	$20,700	$169,186
TOTAL	$7,048,700		$7,193,186

areas: facilities and equipment, and operations and maintenance. The operations and maintenance costs have been escalated to obtain the present value of the 15-year life cycle cost. The total present value cost of a RTR is $413,[illegible]1 in 1990 dollars.

B.5 LORAN-C OFFSHORE FLIGHT FOLLOWING

The costs associated with LORAN-C offshore flight following (LOFF) are not well understood at this time. The system is still in an evaluation phase with the level of performance, and hence the cost of the hardware, yet to be determined. However, the oil industry has established the Gulf Networking Group which intends to pursue the establishment of a LOFF system in the Gulf with or without FAA participation. Therefore, the cost of the LOFF transmitters and communication links are considered to be a sunk cost in this analysis. These costs could be in excess of $2 million if they are not already in place when the FAA is ready to implement LOFF or if the industry's equipment does not meet FAA requirements. There is currently funding for LOFF in the FAA's 1992 budget. The Southwest Region estimates the acquisition costs of the LOFF system to be approximately $1.65 million in 1990 dollars. No estimate of annual O&M costs is available at this time. There will be some airborne user costs also as this equipment will need to be certificated to FAA standards that are yet to be developed.

B.6 AIRPORT SURVEILLANCE RADAR-9

The facilities and engineering costs associated with an airport surveillance radar-ASR9 were obtained from NAS Change Proposal 9710, "ASR 7 & 8 Life Cycle Replacement Cost" (reference 65). The costs were then escalated from 1986 to 1990 dollars. The costs associated with annual operations and maintenance were obtained from the Fiscal Management Branch of the Systems Maintenance Service, ASM-11, at FAA Headquarters. The operations and maintenance costs were then escalated to obtain the present value of the 15-year life cycle cost. The total present value cost of an ASR-9 is $7.19 million.

APPENDIX C
IFR DELAY COMPUTATIONS

This appendix describes the logic and methodology for computing IFR rotorcraft operational delay times at heliports with varying levels of communications and surveillance coverage. Delays for three scenarios are computed: 1) the absence of low altitude communications and surveillance coverage, 2) low altitude communications coverage only, and 3) combined low altitude communications and surveillance coverage. The underlying logic is the same as that used by the FAA for computing the delay reductions derived from installing airport surveillance radars.

The absence of low altitude communications coverage over heliports reduces the rate of IFR approaches and departures and thereby increases the delays pilots and passengers may experience. In such an environment, a single IFR operation prevents any other IFR approach or departure from being performed until the pilot reports the rotorcraft's location or cancels the IFR flight plan. For both departures and approaches, this procedure typically takes 10 minutes. A normal IFR departure from a heliport in the absence of communications begins with a pilot being issued a departure clearance window of 10 minutes. If the pilot departs on average in the middle of this window, 5 minutes is consumed. The other 5 minutes is used as the pilot climbs to or above the minimum communications altitude (4,000 feet is assumed) and reports the rotorcraft's location to air traffic control.

Similar logic is used for the IFR approach. Once the IFR rotorcraft gets cleared for the approach, an average of 8 minutes is required for the rotorcraft to leave the appropriate altitude (again 4,000 feet AGL is assumed) and complete the approach. The other 2 minutes are needed for an attendant at the heliport to cancel the IFR flight plan. Based on one approach or departure every 10 minutes, the theoretical capacity of the heliport is six operations per hour.

In accordance with existing FAA methodology, the statistical distribution of arriving and departing IFR aircraft is assumed to be Poisson with approach and departure requests occurring randomly and operations being performed mutually exclusive of one another. Based on these assumptions, a simple queue with a first-come, first-served discipline can be applied. The equation for delay is from reference 46:

Delay (Minutes) = 60*(Operations per Hour/Theoretical Capactiy)^2/(1 - Operations per Hour/Theoretical Capacity)

The results are presented in table C-1. The queue equations use <u>average</u> number of rotorcraft; therefore, even when an average of one aircraft arrives per hour, delays can result.

TABLE C-1 IFR DELAYS WITHOUT COMMUNICATIONS

AVERAGE NUMBER OF ROTORCRAFT PER HOUR	PROBABILITY OF DELAY	TOTAL DELAY FOR ALL ROTORCRAFT (MINUTES)
1	0.17	2.00
2	0.33	10.00
3	0.50	30.00
4	0.67	80.00
5	0.83	250.00
6	1.00	Theoretical Capacity

Low altitude communications down to the missed approach altitude permits non-radar separation to be applied to air traffic. The FAA has identified three distances, 7.5 miles, 10 miles, and 15 miles, as representative of possible spacings without communications depending on the type of separation procedures employed. Air traffic control towers will probably not be located at most heliports in the future. This eliminates a number of procedural options available, the most important one being timed approaches. Without timed approaches, spacing of 7.5 miles would not be possible. Therefore, only delays associated with 10 and 15 miles spacing will be considered.

Ten mile spacing is most applicable at sites where the initial approach fix is at or below 4,000 feet AGL. This assumes climbs and descents are performed at a rate of 1,000 feet per minute in all phases of flight except while performing the instrument approach. For those areas where the initial approach fix is above 4,000 feet AGL, 15 mile spacing is more applicable.

Consistent with FAA computations, at 10 nautical miles spacing, the average time between touchdown of one IFR rotorcraft and the following rotorcraft is:

$$\frac{\text{10 nautical miles}}{\text{90 knots}} = \text{0.11 hours}$$

which enables 9 landing rotorcraft per hour to be handled at ultimate capacity. With 10 nautical miles separation, the separation between landing and departing rotorcraft is great enough to permit takeoffs without affecting the landing sequence. Therefore, under ideal conditions a maximum of 18 rotorcraft per hour, double the number of landing rotorcraft, could be handled.

TABLE C-2 IFR DELAY WITH COMMUNICATIONS
(10 MILES SPACING)

Average Number of Rotorcraft	Probability of Delay	Total Delay for All Rotorcraft (Minutes)
1	0.06	0.20
2	0.11	0.83
3	0.17	2.00
4	0.22	3.81
5	0.28	6.41
6	0.33	10.00
7	0.39	14.85
8	0.44	21.33
9	0.50	30.00
10	0.56	41.67
11	0.61	57.62
12	0.67	80.00
13	0.72	112.67
14	0.78	163.33
15	0.83	250.00
16	0.89	426.67
17	0.94	963.33

Spacings of 15 nautical miles results in average time between touchdown as being:

$$\frac{15 \text{ nautical miles}}{90 \text{ knots}} = 0.17 \text{ hours}$$

With a minimum of 0.17 hours required between instrument approaches or departures, the maximum number of approaches that can be handled per hour is 6. Approaches and departures can again be performed independently of one another; therefore, under ideal conditions the maximum number of rotorcraft instrument operations that could ultimately be handled is 12 rotorcraft.

At 3 miles separation, which can be obtained with both communications and radar coverages in the terminal area, the total wait which would result are presented in table C-4. In this instance the minimum separation is 3 miles/90 knots = .0333 hours = 2.00 minutes. The theoretical capacity is 30 operations per hour.

TABLE C-3 IFR DELAYS WITH COMMUNICATIONS
(15 MILES SPACING)

Average Number of Rotorcraft	Probability of Delay	Total Delay for All Rotorcraft (Minutes
1	0.08	0.45
2	0.17	2.00
3	0.25	5.00
4	0.33	10.00
5	0.42	17.86
6	0.50	30.00
7	0.58	49.00
8	0.67	80.00
9	0.75	135.00
10	0.83	250.00
11	0.92	605.00

TABLE C-4
IFR DELAYS WITH SURVEILLANCE

Average Number of Rotorcraft	Probability of Delay	Total Delay for All Rotorcraft (Minutes)
1	0.03	0.07
2	0.07	0.29
3	0.10	0.67
4	0.13	1.23
5	0.17	2.00
6	0.20	3.00
7	0.23	4.26
8	0.27	5.82
9	0.30	7.71
10	0.33	10.00
11	0.37	12.74
12	0.40	16.00
13	0.43	19.88
14	0.47	24.50
15	0.50	30.00
[illegible]	0.53	36.57
17	0.57	44.46
18	0.60	54.00
19	0.63	65.64
20	0.67	80.00
21	0.70	98.00
22	0.73	121.00
23	0.77	151.14
24	0.80	192.00
25	0.83	250.00

APPENDIX D EMS HELICOPTER BENEFITS ANALYSIS

There is no doubt that properly equipped EMS helicopters are a critical part of a modern, systematic approach to emergency medical care. People involved in EMS are convinced of the helicopter's value in patient care. Rapid air transport with a skilled medical team aboard has been demonstrated to save lives, reduce morbidity, and enhance regionalization of medical care requiring expensive, special resources (references 39, 40, 42, and 43). However, all of the studies which attempt to quantify the contribution of the helicopter to the EMS system have found it an elusive goal. There are many reasons for this difficulty, and they will be discussed in the following paragraphs. However, they are well summed up by the following quote:

> "The controversies that have surrounded the prehospital management of trauma stem not only from lack of appropriate data, but also from a lack of medical accountability and 'street wise', academic physician involvement within EMS systems. As a result, the approach to EMS trauma has often been over-generalized and debated in terms of simplistic, undimensional concepts, such as 'scoop and run' versus 'field stabilization' without any regard for the type and anatomic location of the injury involved, the efficiency and skill of rescuers, the proximity and actual capabilities of definitive care resources, and the logistics of the prehospital setting. The failure to understand and delineate these variables has lead to conflicting studies and has confused the analysis..." (reference 42).

Furthermore, the benefits documented in the literature are always for VFR conditions and frequently for scene pickups. Neither one of these scenarios is directly applicable to the benefits which are sought herein, namely IFR interhospital transports.

The analysis which follows is the result of an extensive literature search. A computer search was made of all the literature on helicopter EMS from 1980 to date. In addition, several of the authors of the more pertinent articles and the Association of Air Medical Services were contacted directly to verify that no significant articles had been missed. Over 30 articles on helicopter EMS and trauma were reviewed. Although many articles reported a difference between air and ground transported patients' mortality rates, most of them do not support a direct comparison of the mortality rates for the reasons to be discussed in the next paragraph. Only four articles with relevant statistics on mortality reduction were found. No articles were found which attributed specific amounts of time savings to specific amounts of mortality reduction in trauma victims. On the other hand, several articles indicated that small differences in transport time made no difference in patient survivability as long as appropriate medical intervention was initiated quickly and maintained during transport. Since no indication could be found for it in the literature, the EMS benefit equation will not be based on time reductions, as all the other mission efficiency benefit equations are. Instead, the average reduction in mortality for all transports over a year is more appropriate and will be used.

EMS SYSTEM APPROACH

Modern emergency medicine is a team effort, and it is difficult to separate the specific contributions of one particular part of the system. A helicopter is neither a medical nor a therapeutic device. It serves to extend the capabilities of the hospital's emergency department over a large geographic area in a cost effective, timely manner. Personnel and medical equipment delivered to the referring hospital, and a regional communication system to ensure rapid response and coordination are also essential for mortality reduction. Even in the studies which have found increased survival rates for helicopter transports, all have attributed the improved survival rates primarily to other factors, and not to the shortened length of time between injury and arrival at a trauma center. More importance was placed on the decreased interval between time of injury and the start of appropriate advanced life support (ALS) measures by the air transport team at the referring hospital. In other words, the helicopter makes a contribution to an organized EMS system, as does the medical communications system, as does the medical flight team. Furthermore, the medical treatment received at the specialty treatment center, once the patient arrives there, is a relevant factor in the survival rates of patients. Some treatment centers are more effective than others, and they will have an effect on the overall mortality.

Table D-1 summarizes the findings of the four documented cases of mortality reduction with the use of EMS helicopters. All four of the studies compare the mortality of helicopter-transported trauma patients with the mortality predicted by the Major Trauma Outcome Study (MTOS) (reference 35, 36 and 69). This study examines a large patient population (3,133 trauma patients) from 45 trauma centers and correlates trauma scores to probability of mortality. The trauma score is composed of numerous physiologic measures such as respiration rate, pulse rate, blood volume, a "coma score," and so on. The lower the trauma score, the sicker the patient. The MTOS is used as the national norm against which the effect of various trauma treatment regimens can be measured and compared. Only studies which compare the mortality rate for air ambulance-transported patients against the MTOS predicted mortality have any relevance as far as the computation of mortality reduction is concerned. All the studies which compute separate mortality rates for ground-transported trauma patients and air-transported trauma patients are not relevant here, since the two mortality rates cannot be meaningfully compared.

One possible reservation about using the MTOS as a measure of helicopter transport effectiveness is that 17 percent of the patient population of the MTOS is made up of helicopter transports; this could skew the expected results in some manner. However, if this subgroup of the study population is removed, the overall MTOS predicted mortality rate would go up and the helicopter would appear to contribute to an even greater reduction in mortality (reference 33). Thus, all of the reported mortality reductions related to the use of helicopter transports, based on comparisons to MTOS predicted mortality, can be considered conservative. However, the amount of mortality reduction attributable to the helicopter-transported population is not reported in the literature.

TABLE D-1 HELICOPTER EMS MORTALITY REDUCTION

SOURCE	MORTALITY		PERCENT MORTALITY		PERCENT DIFFERENCE	COMMENTS
	ACTUAL	PREDICTED	ACTUAL	PREDICTED		
BAXT '83 (reference 39)	10/150	20.62/150	6.67%	13.75%	7.08%	Air Evacuation (Rural Area)
	19/150	14.79/150	12.67%	9.86%	-2.81%	Ground Evacuation (Urban Area)
BAXT '85 (reference 33)	191/1273	240/1273	15.0%	18.85%	3.85%	Seven Center Average
	27/370	43.88/370	7.30%	11.86%	4.56%	Trauma Center 1
	61/215	70.95/215	28.37%	33.00%	4.63%	Trauma Center 2
	19/230	29.86/230	8.26%	12.98%	4.72%	Trauma Center 3
	33/113	34.5/113	29.20%	30.53%	1.33%	Trauma Center 4
	7/58	10.43/58	12.07%	17.98%	5.91%	Trauma Center 5
	19/166	25.19/166	11.45%	15.17%	3.72%	Trauma Center 6
	25/121	25.92/121	20.66%	21.42%	0.76%	Trauma Center 7
BOYD '88 (reference 3)	16/73	29.7/73	21.9%	29.7%	7.8%	ALL INTERHOSPITAL TRANSFERS
TOYCEN '90 (reference 40)	6/83	7/83	7.2%	8.4%	1.2%	Ground Evaluation (Urban Area)
	17/96	24/96	17.7%	25.0%	7.3%	Air Evacuation (Rural Area)

BAXT '83 - Scene Evacuations to the Same Center
BAXT '85 - Scene Evacuations to 7 Different Centers
BOYD '88 - All Interhospital Transfers
TOYCEN '90 - Scene and Interhospital Evacuations

Another potential problem with the application of the MTOS to interhospital transfer of trauma patients is the selection of the study group. An EMS helicopter typically arrives at the referring hospital about 30 minutes after the injury occurs. A ground ambulance typically arrives at the accident scene less than 10 minutes after the injury occurs. In the intervening 20 minutes, some patients are going to die, either because of the severity of their injury and/or their state of health, no matter what treatment they are given. Thus, some people argue that because of the time lag between the occurrence of the injury and the arrival of the helicopter, the helicopter is picking up a subgroup of the total trauma victim population. This subgroup is heavily weighted with survivors, because the majority of the victims that were going to die have already done so in the first 30 minutes before the helicopter arrived on the scene. This is a problem that has not been resolved by the medical statistics community as of this writing.

There are several points which must be considered before evaluating the data presented in table D-1. The first is the nature of the trauma scoring system itself. It is not an exact measure of a patient's condition and it is also time sensitive. Studies have shown that the scoring method has a sensitivity rate of 80 percent, meaning that 20 percent of the severe injuries are not detected at the scene of the accident (reference 36). The scoring method also has a specificity of 75 percent, meaning that it overestimates the severity of injuries 25 percent of the time. Also, the time elapsed between the injury and the scoring of the patient may have an effect. If the patient is evaluated very soon after the injury, as is typical in urban areas served primarily by ground-based ambulances, many of the symptoms may not have had time to manifest themselves to an identifiable level (reference 44). Thus the severity of trauma scores and the deaths resulting from them may be different for trauma patients from urban and rural areas. For example, a ground ambulance may pick up a trauma patient 10 minutes after the accident, before the symptoms of the injuries can be identified, and transport him/her back to a hospital where he/she might die 10 minutes later with a relatively high trauma score. On the other hand, a helicopter ambulance does not usually arrive until approximately 30 minutes after the accident. The injuries have had time to manifest themselves and are more likely to be identified.

Only one study, Baxt '83 (reference 39), compares the mortality rates of air transported patients (6.67 percent actual, 13.75 percent predicted) to ground transported patients (12.6 percent actual, 9.86 percent predicted). All patients in the study were treated at the scene of the accident and transported to the same trauma center. While the magnitude of the actual mortality was lower for air transports than for ground transports, this is not the important factor here. The study is really comparing the differences between the MTOS predicted mortality and the actual mortality for each group. This is necessary because it is not possible to match all the subjects in each transport group for age, health and physical condition, severity and location of injury, time until initial medical intervention, effectiveness of initial medical intervention, and so on. In addition, there is the variability of the trauma scoring system itself.

Only patients treated and transported by helicopter had a statistically significant reduction in mortality rate ($p<.001$). The increase in mortality

rate for the ground-transported group was not statistically significant ($p<.05$). The air-transported group had an actual mortality 7.08 percent lower than predicted by the MTOS.

Baxt also noted that although mortality was reduced the most for the air-transported group, the time elapsed between injury and arrival at the trauma center for that group was 23 minutes longer than for the ground-transported group, 58 and 35 minutes respectively. This finding is not in keeping with the concept of the faster the evacuation, the lower the mortality rate. Rather, it indicates the importance of quickly stabilizing the patient at the scene. In addition, the air-transported group had worse trauma scores, yet they had a lower overall mortality rate. Baxt offers the following explanation. The ground-transported patients were usually from urban areas, and initial treatment was begun on average 7 minutes after injury by highly trained paramedics. The air-transported patients, on the other hand, were usually from rural areas, and initial treatment was begun on average 10 minutes after injury by less medically qualified emergency medical technicians (EMT) from the local ground ambulances. The rural ambulance service would then ground-transport the patient to the local emergency room. It is important to remember that in this study most of the air-transported patients were first transported by ground ambulances and that they received a lower level of initial medical intervention. Only after the initial ground transport was the air transport initiated. The time until initial physician contact for the ground and air groups was 35 minutes and 34 minutes, respectively. Baxt suggests that it is possible the condition of the paramedic-treated, ground-transported, urban group may have actually improved during transports and, conversely, the EMT-treated air group may have deteriorated during the initial ground transport to the local hospital due to the delay in application of advanced life support. This is offered as a possible explanation for why the ground-transported patients had a higher mortality rate although they had less serious trauma scores. This hypothesis seems to be supported by later studies which find little or no value for helicopter transports in urban areas served by sophisticated ground ambulance service with quick response times and skilled medical personnel on board (reference 2). However, these studies do support the use of helicopters to extend the range of the EMS system to rural areas. Another explanation, of course, is the selection of a population of survivors by the 30-minute delay in the arrival of the helicopter as discussed above.

Baxt performed another study on the effect of helicopter transport on blunt trauma victims in 1985. This time, however, there was no comparison made between air and ground transports, possibly because useful comparisons could not be made in the 1983 study. The 1985 effort was a multicenter study of seven different trauma centers. All patients were treated at the scene of the accident and then transported back to the trauma centers. The reduction in MTOS predicted mortality ranged from 0.76 percent to 5.91 percent, with a weighted average for all of the centers of 3.85 percent. The average mortality reduction and all of the individual center mortality reductions are lower than the reduction reported for the air-transported group in the 1983 study. However, this can be explained by the fact that this study combines the patients from urban and rural populations into one group. These groups were separate in the 1983 study. By including patients from the urban area

around the hospital, the helicopter was probably getting to some of the patients that were going to die no matter what treatment was given and/or patients with high trauma scores but serious injuries which had not yet had time to manifest themselves. The inclusion of this type of patients would lead to an increase in the actual mortality rate and also a decrease in the MTOS predicted mortality rate. Therefore, the difference between the actual and the predicted mortality for air-transported trauma patients is lower in this study than in the other three studies.

Another study which quantifies the effect of helicopters on trauma mortality is by Boyd '88. Only interhospital transfers were used in the study population, and the MTOS predicted mortality was reported. The actual mortality was 21.9 percent and the MTOS predicted mortality was 29.7 percent. The difference between the actual and the predicted is 7.8 percent. This percentage reduction in predicted mortality is amazingly close to the 7.08 percent reduction reported for the air-transported patients in Baxt '83. The air-transported patients from that study had a similar lag in time before definitive life support measures could be given.

The last study which quantifies the effect of the helicopter on trauma mortality was done by Toycen in 1990. This study involved air and ground transport of trauma patients, both from the scene and interhospital transfers. Most of the ground transports were made from within the local urban area directly from the scene of the accident. Most of the air transports were interhospital. The MTOS predicted mortality for the air-transported group was 25 percent. The actual mortality recorded was 17.7 percent, which is a difference of 7.3 percent. This reduction in mortality was statistically significant ($p<0.025$). No significant difference in predicted (7.2 percent) versus actual (8.4 percent) mortality was found in the ground-transported patients.

While it is not possible to directly compare the results of the two Baxt, the Boyd, and the Toycen studies because they deal with different types of transports, they all dealt with populations that had a lag of approximately 1/2 hour before advanced life support was administered. This is consistent with the time lag experienced with interhospital transfers performed today. From this survey of the literature, it can be concluded that interhospital transports in EMS systems using helicopters may contribute to a reduction in predicted mortality of between 7.1 percent and 7.8 percent.

Despite all of the confounding variables discussed above, in order to quantify the benefits of operating an EMS helicopter in IFR conditions, an estimate of the amount of reduced mortality attributable to the helicopter must be made. Obviously, some simplifying assumptions must be made. For the purposes of this study, the benefits derived from each separate part of an EMS system will be assumed to be dependent on the others. In other words, the benefits could not have been achieved without the contribution of all of the components. Thus, the reduced mortality reported as the result of an EMS system which uses helicopters will be assumed to be impossible to achieve without the use of the helicopter. This is not meant to diminish the importance of the other parts of the system, as the reduced mortality reported probably could not have been achieved without them either.

The equation which will be used to calculate the helicopter air ambulance benefits is as follows:

(Population) X (Transports/Population/Year) X (% Interhospital Transfers) X (% Trauma Patients) X (% Mortality Reduction) X (% IFR wx/(1 - % IFR wx) X (Value of Human Life)

Where: Population = the population of the average EMS operator's cross-country operating area, approximately 145 miles.

(Transports/Population/Year) = 50 (urban area) or 275 (rural area) transports per 100,00 population per year. This estimate was developed by Amherst Associates of Chicago, Illinois.

Note: (Population) X (Transports/Population/Year) = transports per year exists for 26 of the 50 sites chosen for analysis. The data was collected by the Journal of Air Medical Transport (JAMT) but is unpublished. The number of transports for the 10 cities with the highest number of EMS transports was published by JAMT in May 1990. The actual number of transports will be used for the sites for which that data exists.

(% Interhospital Transfers) = approximately 75 percent of all EMS missions are for interhospital transfers on a national basis. Regional averages are also available from the JAMT for the percent of interhospital transfers. The regional averages will be used in calculating benefits.

(% Trauma Patients) = approximately 40 percent of all interhospital transports are for trauma patients with life-threatening injuries. This number was derived through conversations with physicians associated with helicopter EMS programs.

(% Mortality Reduction) = approximately 7.5 percent of the trauma patients transported on EMS helicopters would die without the benefit of a well-developed EMS system of which the helicopter is a critical element. This percentage is based on the studies cited earlier in this appendix.

(% IFR wx/(1 - % IFR wx)) = a correction factor for the number of missions affected by adverse weather conditions. The denominator (1 - % Weather) corrects the annual number of missions flown upward to the number of missions which would have been flown if weather conditions had been VFR 100 percent of the time. The numerator (% Weather) reduces the annual number of missions flown to the number possible in the local area with the weather minimums discussed in section 8.1. Data on the local weather conditions is derived from the FAA's Airport Specific File using the methodology discussed in appendix E.

(Value of Human Life) = $1,500,000 as per the report, Economic Values For Evaluation of Federal Aviation Administration Investment and Regulatory Programs (reference 66), and the update bulletin published in October 1990, APO Bulletin APO-90-1 (reference 67).

APPENDIX E
WEATHER DATA MODEL

The weather data provided in the FAA's Airport Specific File (ASF) is derived from the national average weather data (NAWD) and corrected with site specific weather data. However, the ASF data is organized in such a way that the joint (combined) probabilities of only eight specific combinations of ceiling and visibility limits being exceeded are reported. For the purposes of this study, unconditional (independent) probabilities are of more value than joint probabilities, since the unconditional probabilities will allow the many varied combinations of ceiling and visibility minimums reported by the operators to be computed. It is not possible to calculate all of the various combinations of ceiling and visibility directly from the ASF data.

For example, one EMS/H operator reported day/local minimums of 500 foot ceiling and 1 mile visibility. The ASF data contains data for the combined limits of ceiling less than or equal to 400 feet and visibility less than or equal to 1 mile, or for the combined limits of ceiling less than or equal to 600 feet and visibility less than or equal to 1.5 miles. Nothing in between is reported. Neither category in the ASF exactly fits the operator's minimums. The reported probabilities for the two categories are 1.0 percent and 3.38 percent, respectively. The model developed herein computes the joint probability for 500/1 at the operator's location to be 1.6 percent. Thus, it can be seen that a greater degree of flexibility has been obtained by using the independent probabilities than would be possible using the ASF data alone.

NATIONAL AVERAGE WEATHER DATA

Table E-1 contains the national average weather data which was linearly interpolated directly from a table of NAWD in appendix C of the report Development of Revised and Expanded Airport Specific File Data for the Airport Criteria Data System (reference 18). Table C-1 gives the average joint probabilities of either the ceiling or the visibility minimums, or both, being exceeded for the entire United States. There are several justifications for the use of linear interpolation on the NAWD. The ASF itself uses linear interpolation of NAWD in order to fill gaps in the reported data. The ASF reports eight different combinations of ceiling and visibility minimums, but the data source used in generating the ASF weather data contains only six combinations. Linear interpolation, based on the NAWD, was used to expand the data to eight combinations. In appendix D of the ASF report, there is an explanation of the method of linear interpolation used. In appendix E of the ASF, there are numerous graphs depicting the linear nature of the probability data when either the ceiling or the visibility limit is held constant. The method of interpolation suggested in appendix D of the ASF was not adopted for this report. It was considered to be less accurate than the method described herein, since it relied upon the joint probabilities.

TABLE E-1 PLOT OF NATIONAL AVERAGE WEATHER DATA

Ceiling (feet)	Visibility (miles) 1/2	3/4	1	1-1/2	2	2-1/2	3
200	1.12	1.52	2.02	3.14	4.46	5.78	7.10
300	1.48	1.79	2.22	3.26	4.55	5.84	7.13
400	2.13	2.37	2.72	3.63	4.85	6.07	7.29
600	3.67	3.84	4.10	4.82	5.88	6.93	7.99
800	5.46	5.60	5.81	6.40	7.32	8.23	9.15
1000	7.24	7.36	7.54	8.05	8.86	9.67	10.48
1200	8.67	8.78	8.95	9.42	10.17	10.93	11.69
1500	10.82	10.92	11.06	11.47	12.15	12.82	13.50

A national average percentage of weather observations with ceilings or visibilities less than selected values. Example: 1.79 percent of the time, the ceiling is less than 300 feet, or the visibility is less than 3/4 mile, or both.

Figures E-1 and E-2 illustrate the piecewise linear nature of the national average weather data. Figure E-1 illustrates the piecewise linear nature of the data when the ceiling is fixed. Note that the probability is a piecewise linear function of the visibility for all ceiling values. Figure E-2 illustrates the piecewise linear nature of the data when the visibility is fixed. Note that the probability is a piecewise linear function of the ceiling for all visibility values. Several site specific plots of independent ceiling and visibility probabilities were also developed. In all cases, the plots were found to exhibit the same piecewise linear behavior as the NAWD model.

In order to derive the unconditional probabilities for the ceiling and visibility limits being exceeded, the data was linearly extrapolated to zero percent probability for both the ceiling and the visibility percentages.

Table E-2 is a reconstruction of the NAWD using the unconditional probabilities derived from the NAWD and the climatic mission success indicators (CMSI) model (described in the following paragraph) for combining unconditional weather probabilities to produce a joint weather probability. Table E-2 presents: 1) the extrapolated values of the unconditional probabilities of a 0 foot ceiling and 0 nm visibility, and 2) the computed values for the same weather data as given for the national average weather data in table E-1.

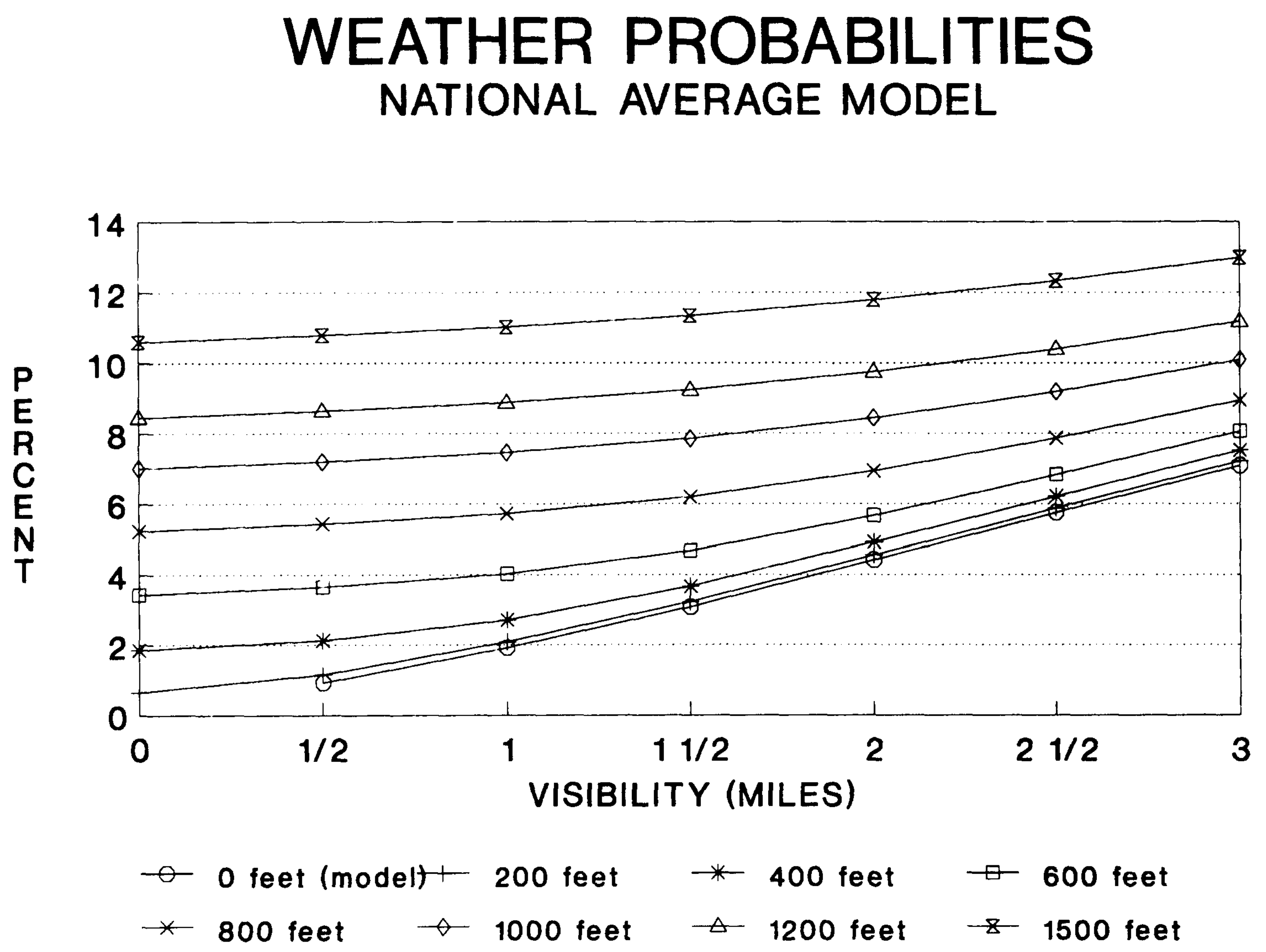


FIGURE E-1 CEILING PROBABILITIES AS A FUNCTION OF VISIBILITY

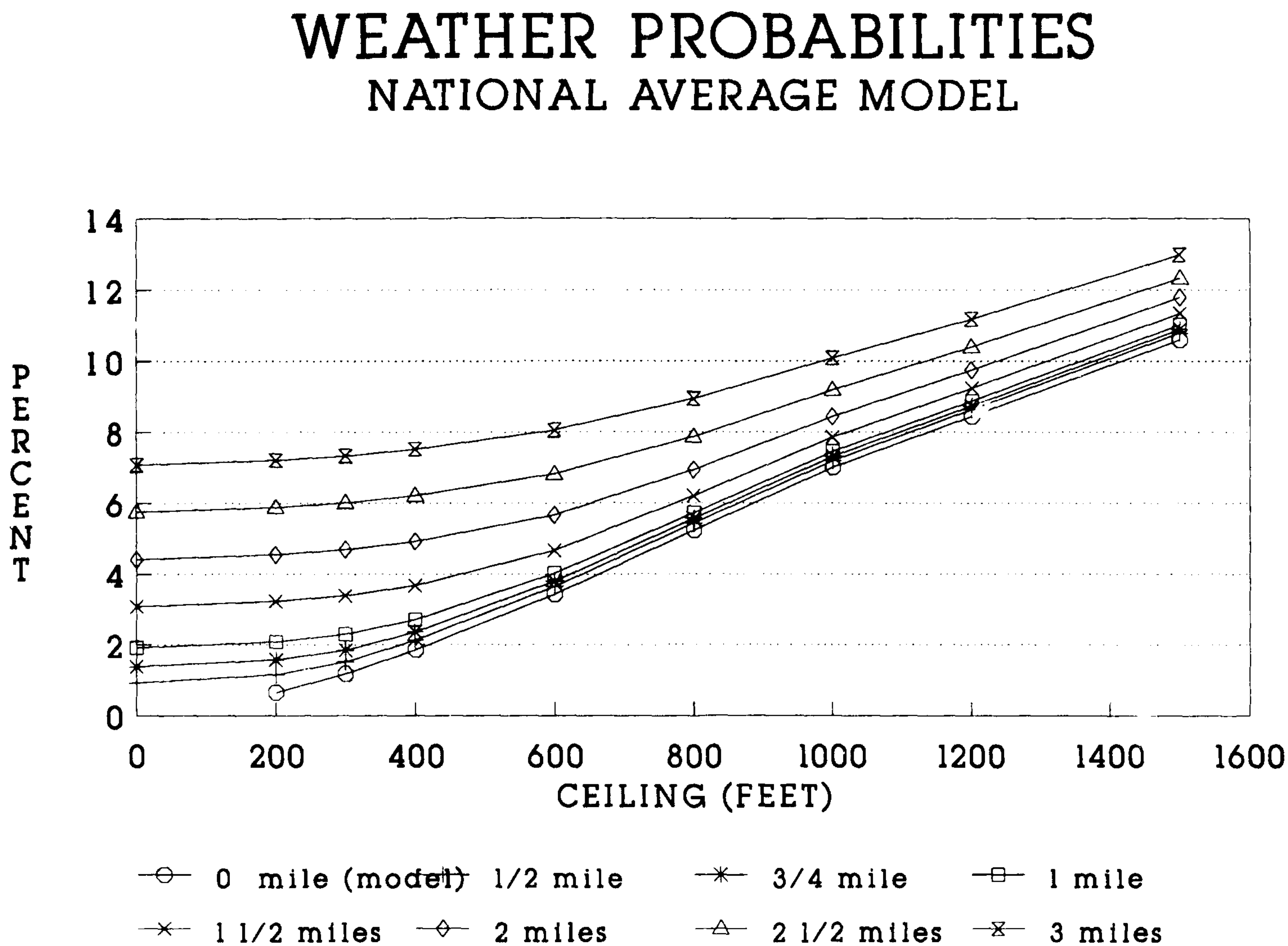


FIGURE E-2 VISIBILITY PROBABILITIES AS A FUNCTION OF CEILING

TABLE E-2 PLOT OF CALCULATED AVERAGE WEATHER DATA

K = 0.813

Ceiling (feet)	Visibility (miles) 0	1/2	3/4	1	1-1/2	2	2-1/2	3
0		0.93	1.39	1.92	3.08	4.41	5.75	7.08
200	0.66	1.16	1.58	2.09	3.23	4.55	5.88	7.21
300	1.18	1.52	1.85	2.30	3.39	4.69	6.01	7.33
400	1.86	2.13	2.36	2.71	3.67	4.92	6.21	7.52
600	3.43	3.65	3.80	4.02	4.67	5.67	6.83	8.06
800	5.23	5.43	5.56	5.72	6.20	6.94	7.87	8.94
1000	7.01	7.20	7.32	7.46	7.86	8.44	9.19	10.09
1200	8.45	8.64	8.74	8.88	9.24	9.75	10.40	11.18
1500	10.60	10.79	10.89	11.02	11.34	11.79	12.33	12.98

The computed values are based upon using the independent probabilities from the linear extrapolation in the following Climatic Mission Success Indicators (CMSI) equation:

$$P_{cv} = (P_c + P_v)/2 + [((P_c + P_v)/2)^2 - (K * P_c * P_v))]^{1/2}$$

Where P_{cv} is the joint probability of a ceiling/visibility combination
- P_c is the unconditional probability of the ceiling limit being exceeded
- P_v is the unconditional probability of the visibility limit being exceeded
- K is a correlation factor used to represent the dependency of ceiling and visibility probabilities

The CMSI equation can be found in Climatic Models That Will Provide Timely Mission Success Indicators For Planning and Supporting Weather Sensitive Operations (reference 68), contract number AFGL-TR-78-0308, page 3, equation 4, where its use is thoroughly explained. Basically, the procedure is to enter the unconditional probability of ceilings, the unconditional probability of visibilities and a K-value into the CMSI equation.

Table E-2 was developed as a check of both the CMSI equation and of the validity of linear extrapolation of the data in the NAWD to produce the unconditional probabilities. First, the average K-value of the NAWD data in table C-1 was computed by using the CMSI equation with the extrapolated 0 foot ceiling and 0 mile visibility values and solving for K instead of for P_{cv}. A K-value of 0.813 was found to be the average for the NAWD. Next, using a K-value of 0.813, the values in table C-2 were calculated. Note that in half the cases the difference is less than 0.1 percent and the difference is never greater than 0.6 percent. In addition the error is never more than 5 percent of the NAWD value. Thus, it appears valid to used the extrapolated, unconditional values for ceiling and visibility along with the CMSI equation.

This model of the NAWD, called the unconditional NAWD model, was then used to compute location specific weather probabilities.

WEATHER DATA ANALYSIS METHODOLOGY

The unconditional NAWD model was used to calculate the percentage of time that a specific EMS/H operator cannot fly due to the various combinations of weather minimums considered in the main body of this report. Several steps were required before application of the model. First, a computer program was written to compare all of the joint probabilities in the ASF with the joint probabilities computed with the unconditional NAWD model. The ratio of the NAWD model probability to the ASF probability was computed to produce an SS-factor (site specific factor) and stored in a new data base that contains the same eight combinations of weather data as the ASF. This database is used to convert the unconditional NAWD model data to site specific weather probabilities.

The file of SS-factors was entered into a database and linked to the EMS database according to the county of the EMS operator's base. Then, a computer program was written and used to calculate the percentage of time that each EMS/H operator cannot operate under the various weather minimums. Before the CMSI equation could be applied in each location, it was necessary to linearly interpolate for the specific ceiling/visibility limits of interest for both the SS-factor of the location and for the ceiling/visibility limits in the unconditional NAWD model . Once the program had performed the interpolations, the CMSI equation was applied, and the joint probability was calculated and stored in the EMS database.